INSTRUCTION MANUAL

TYPE

323

OSCILLOSCOPE

Tektronix, Inc.
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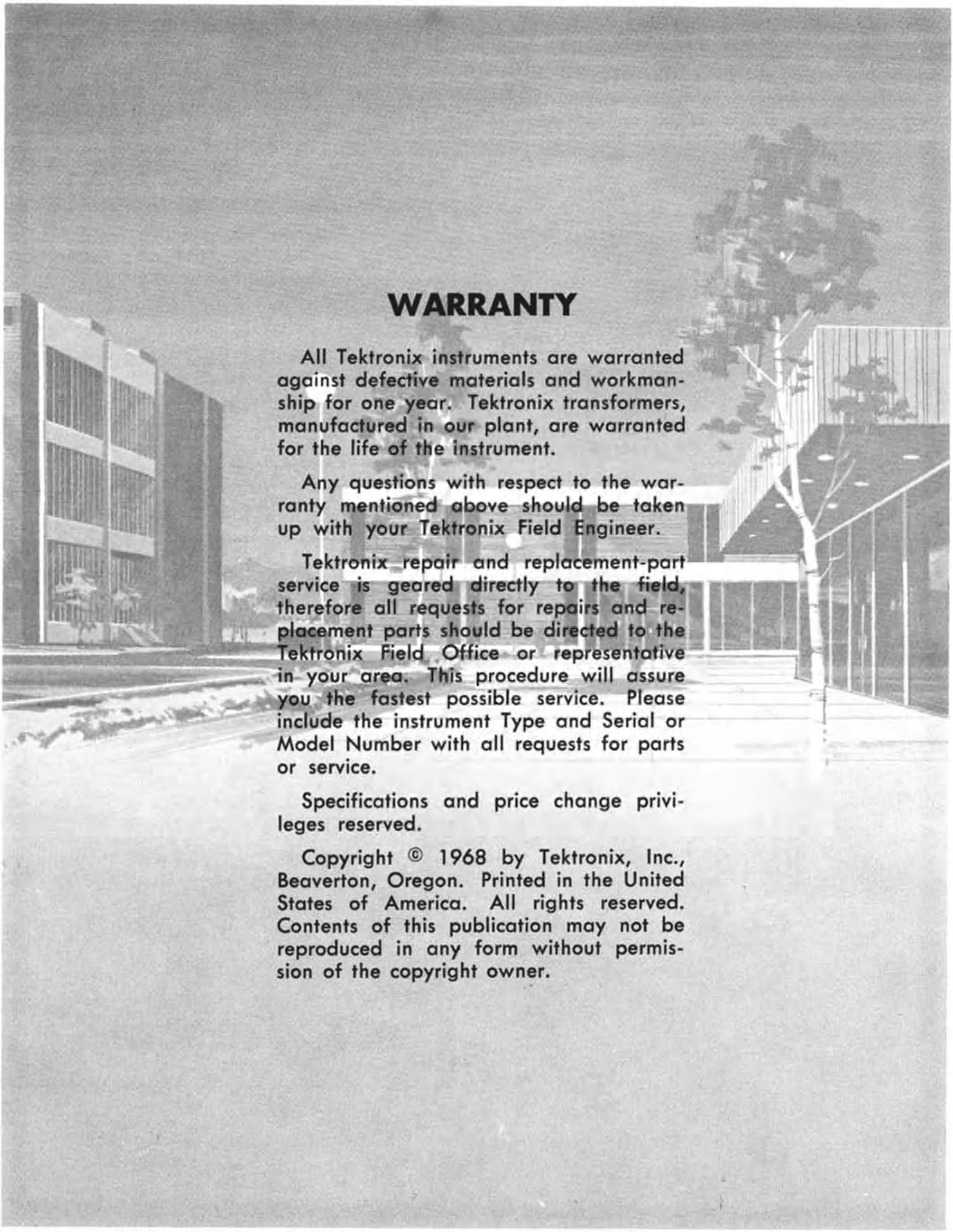

WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial or Model Number with all requests for parts or service.

Specifications and price change privileges reserved.

CONTENTS

Abbreviations and symbols used in this manual are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this manual.

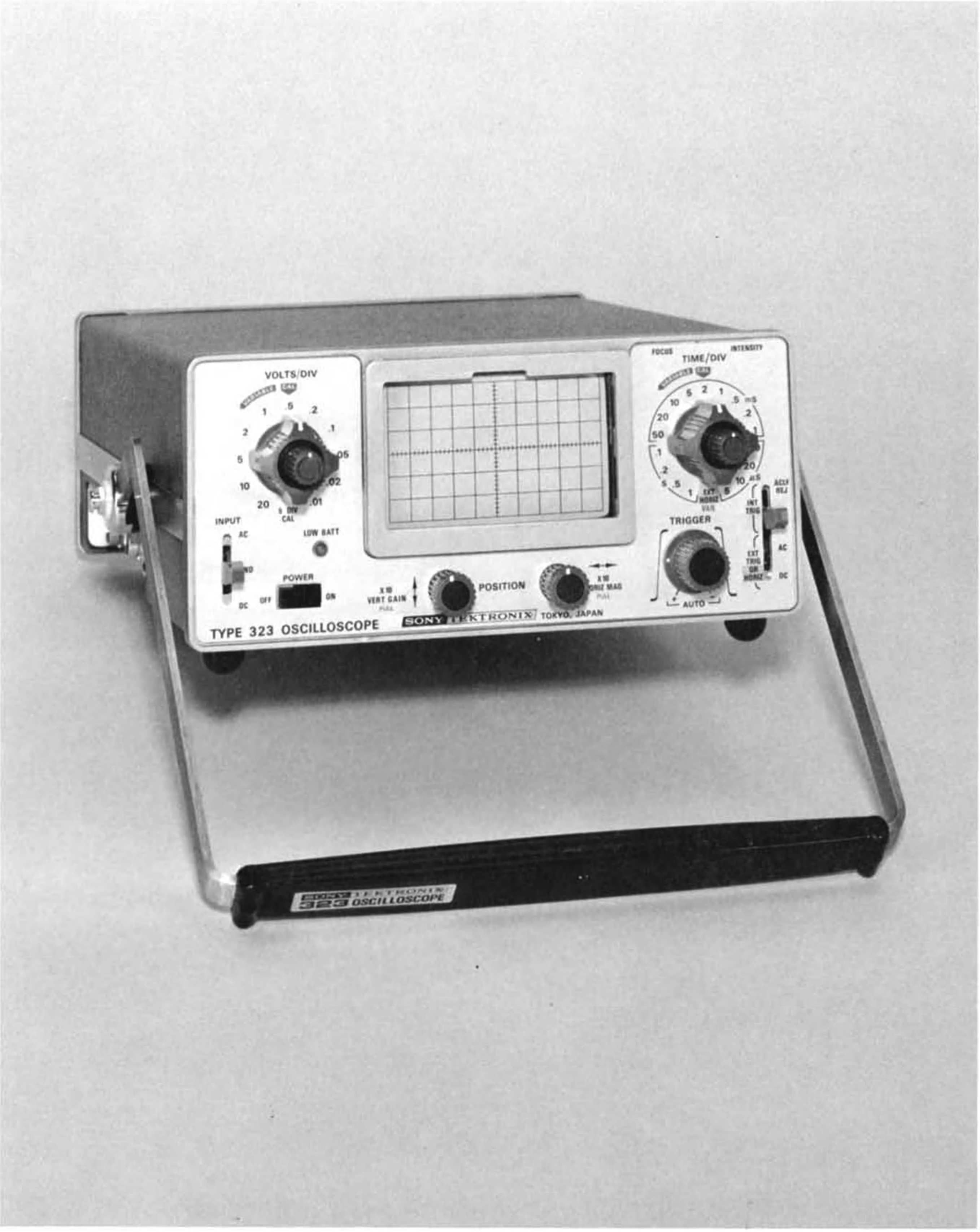

Fig. 1-1. Type 323 Oscilloscope.

SECTION 1
TYPE 323 SPECIFICATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

The Sony/Tektronix Type 323 Oscilloscope is a solid-state portable instrument that combines small size and light weight with the ability to make precision waveform measurements. The instrument is mechanically constructed to withstand the shock, vibration and other extremes of environment associated with portability. A DC to four megahertz vertical system provides calibrated deflection factors from 0.01 to 20 volts/division (0.001 volt/division minimum with reduced frequency response). The trigger circuits provide stable triggering over the full vertical bandwidth. The horizontal deflection system provides calibrated sweep rates from one second to five microsceonds/division. A ×10 horizontal magnifier allows each sweep rate to be increased 10 times to provide a maximum sweep rate of 0.5 microseconds/division in the 5 μs position. X-Y measurements can be made by applying the vertical (Y) signal to the VERT INPUT connector and the horizontal (X) signal to the EXT TRIG OR HORIZ INPUT connector (TIME/DIV switch set to EXT HORIZ, Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ).

The Type 323 can be operated from any one of three power sources; AC line, external DC or internal rechargeable batteries. A power regulator circuit assures that instrument performance is not affected by variations in internal battery charge level, applied DC voltage or AC line voltage and frequency. Maximum total power consumption is 4.5 watts for external DC or internal battery operation and 14 watts maximum when operated from an AC line. Operation from an AC line also provides full or trickle charging for the internal batteries.

The electrical characteristics which follow are divided into two categories. The instrument is checked in the Performance Requirement and Calibration sections of this manual against the characteristics listed in the Performance Requirement column. However, the items listed in the Operational Information column either provide further information concerning a Performance Requirement or explain an operating feature which is not checked in this manual. The Performance Check procedure given in Section 5 of this manual provides a convenient method of checking the items listed in the Performance Requirement column. The following electrical characteristics apply over a calibration interval of 500 hours at an ambient temperature range of —15° C to +55° C, except as otherwise indicated. Warm-up time for given accuracy is 10 seconds.

ELECTRICAL CHARACTERISTICS

VERTICAL DEFLECTION SYSTEM

Characteristic	Performance Requirement	Operational Information
Deflection Factor		
Calibrated range ×1 gain	0.01 to 20 volts/division in 11 steps.	Steps in 1-2-5 sequence.
×10 gain	0.001 to 2 volts/division in 11 steps.	
Accuracy	Within 3% of indicated deflection with VERT ×1 GAIN and VERT ×10 GAIN correctly adjusted.	VARIABLE VOLTS/DIV control set to CAL.
Uncalibrated (variable) range	Provides continuously variable deflection factors between the calibrated steps. Extends maximum uncalibrated deflection factor to at least 50 volts/division.	
Low-Frequency Linearity	0.1 division, or less, compression or expansion of a center-screen two-division signal when positioned two divisions to the vertical extremes of the graticule area.	Measured with one-kilohertz or less square wave.

VERTICAL DEFLECTION SYSTEM (cont)

Characteristic	Performance Requirement	Operational Information
Bandwidth with Four-Division Reference		
Upper —3 dB Point, AC (capacitive) and DC (direct) Coupled, with Equivalent Risetime (with or without P6049 Probe)		VARIABLE VOLTS/DIV control set to CAL. Risetime calculated from bandwidth measurement using the formula: $t_r = \frac{360}{BW}$ Where: t_r = *Risetime in nanoseconds.* BW = Bandwidth in megahertz.
$\times 1$ gain	Four megahertz or greater, and 90 nanoseconds or less.	
$\times 10$ gain	2.75 megahertz or greater, and 130 nanoseconds or less.	
Lower —3 dB Point, AC (capacitive) Coupled ($\times 1$ or $\times 10$ gain)		VARIABLE VOLTS/DIV control set to CAL.
Without probe	Two hertz or less.	
With P6049 Probe	0.2 hertz or less.	
Step Response		
Aberrations at .01 VOLTS/DIV	Peak aberrations not to exceed +2% or —2%; total peak-to-peak aberrations not to exceed 3% (—15°C to +55°C).	VARIABLE VOLTS/DIV control set to CAL
Aberrations at all other VOLTS/DIV switch positions 0° C to +55° C	Peak aberrations not to exceed +3% or —3%; total peak-to-peak aberrations not to exceed 3%.	
—15°C to 0°C	Peak aberrations not to exceed +4% or —4%; total peak-to-peak aberrations not to exceed 4%.	
Positioning effect on aberrations		Negligible with signal on screen.
Probe effect on aberrations		Negligible.
Overload Recovery		
0° C to +40° C		One microsecond, or less, to stabilize after a signal change at the VERT INPUT connector equivalent to +30 or —30 divisions of deflection.
—15° C to +55° C		Two microseconds, or less, to stabilize after a signal change at the VERT INPUT connector equivalent to +30 or —30 divisions of deflection.
Displayed Noise at 0.001 Volt/Division		
Driven from 50-ohm termination or P6049 Probe		0.1 division, or less.
Input Coupling Mode	AC (capacitive) coupled, DC (direct) coupled and internally grounded.	Selected by front-panel INPUT switch.
Maximum Input Voltage (AC or DC input coupling)		
With or without probe		500 volts DC + Peak AC.
Input RC Characteristics		Without probe / With P6049 Probe
Input resistance		One megohm, ±2%. / 10 megohm, ±2%.
Input capacitance		47 picofarads, ±4 pF. / Less than 13.5 picofarads.

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VERTICAL DEFLECTION SYSTEM (cont)

Characteristic	Performance Requirement	Operational Information
Trace Shift Due to Input Current +20° C to +30° C	0.085 division, or less, at 0.001 volt/division.	Equivalent to 85 picoamperes, or less.
−15° C to +55° C	0.7 division, or less, at 0.001 volt/division.	Equivalent to 0.7 nanoamperes, or less.
Trace Drift Drift with time Short term (temperature and line voltage held constant)		0.2 division, or less, during any minute after 10-second warm up.
Long term (line voltage held constant, temperature held constant between +20° C and +30° C)		0.2 division, or less, during any hour after 10-second warm up.
Drift with line voltage change (temperature held constant)		0.1 division, or less, with line voltage change from 90 to 136 volts or 180 to 272 volts.
Drift with temperature (line voltage held constant)		Two divisions, or less, from reference at +25° C with temperature change from −15° C to +55° C.

TRIGGERING

Characteristic	Performance Requirement	Operational Information
Trigger Source	Internal or external	Selected by front-panel Trig/Horiz Coupling switch.
Trigger Coupling Internal	AC (capacitive) coupled. AC (capacitive) coupled, low-frequency reject.	
External	AC (capacitive) coupled. DC (direct) coupled.	
Trigger Mode	Manual triggering adjustable for desired level. Automatic triggering at average level of triggering waveform; free-running baseline in absence of adequate trigger signal.	Selected by front-panel TRIGGER control.
Trigger Polarity	Sweep can be triggered from positive-going or negative-going portion of trigger signal.	
Trigger Sensitivity (manual and automatic) Internal	See Fig. 1-2.	Correct triggering in the automatic mode may not be obtained for some signals such as low-duty cycle or low-repetition rate signals.
External	See Fig. 1-2.	
External Trigger Input RC characteristics		One megohm ±2% paralleled by 62 picofarads ±4 pF.
Maximum input voltage		300 volts DC + peak AC.
TRIGGER control range EXT TRIG OR HORIZ ATTEN at 1×	+0.8 volt to −0.8 volt.	
EXT TRIG OR HORIZ ATTEN at 10×	+8 volts to −8 volts.	

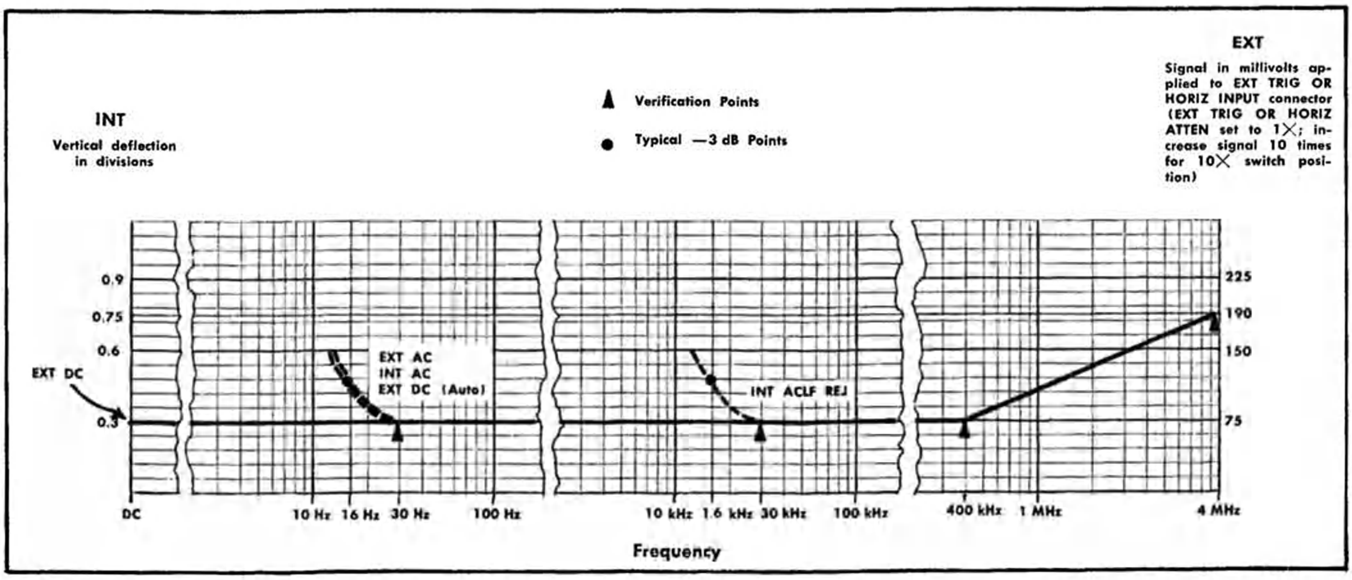

Fig. 1-2. Trigger sensitivity specification limit curve.

HORIZONTAL DEFLECTION SYSTEM

Characteristic	Performance Requirement	Operational Information
Calibrated Sweep Rates	Five microseconds to one second/division in 17 steps.	Steps in 1-2-5 sequence. Each sweep rate can be increased 10 times with ×10 magnifier. Extends fastest sweep rate to 0.5 microsecond/division.
Unmagnified Time Measurement Accuracy (over center eight divisions of graticule)		VARIABLE TIME/DIV control set to CAL.
5 μs to 0.2 s/DIV	Within 3%.	
0.5 s to 1 s/DIV	Within 4%.	
Magnified Time Measurment Accuracy (over center eight divisions of graticule, equivalent magnified sweep rates given)		VARIABLE TIME/DIV control set to CAL. Exclude first two and last two divisions of total magnified sweep length at 0.5 and 1 microsecond/division.
2 microseconds to 20 milliseconds/division	Within 4%.	
0.5 and 1 microsecond, 50 milliseconds and 0.1 second/division	Within 5%.	
Uncalibrated (variable) Sweep Rates	Provides continuously variable sweep rates between the calibrated steps. Extends slowest uncalibrated sweep rate to at least 2.5 seconds/division.	
Normal/Magnified Registration		±1 division, or less, horizontal trace shift when switching from normal to magnified sweep. Internally adjustable.
Sweep Length	10.5 to 11 divisions.	Internally adjustable.

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HORIZONTAL DEFLECTION SYSTEM (cont)

Characteristic	Performance Requirement	Operational Information
External Horizontal Input Deflection factor		
×10 HORIZ MAG pulled out, EXT TRIG OR HORIZ ATTEN set to 1×	20 to 30 millivolts/division.	EXT HORIZ VAR (VARIABLE TIME/DIV) control set to CAL.
×10 HORIZ MAG pushed in, EXT TRIG OR HORIZ ATTEN set to 1×	200 to 300 millivolts/division.	
×10 HORIZ MAG pulled out, EXT TRIG OR HORIZ ATTEN set to 10×	200 to 300 millivolts/division.	
×10 HORIZ MAG pushed in, EXT TRIG OR HORIZ ATTEN set to 10×	Two to three volts/division.	
Variable deflection factor range	10:1, or greater.	
Bandwidth with 10 division reference	DC to 10 kilohertz, or greater.	
Dynamic range		At least 20 divisions (+2.5 volts to −2.5 volts) with ×10 HORIZ MAG switch pulled out, EXT TRIG OR HORIZ ATTEN switch set to 10×, EXT HORIZ VAR control set to CAL. Dynamic range is reduced when any of these controls are changed from the above positions.

CALIBRATOR

Waveshape	Square wave.		
Output Voltage	Zero to +0.5 volts peak to peak.		
Repetition Rate	750 hertz.		
Accuracy	+20° C to +30° C	−15° C to +55° C	
Voltage	Within 1%	Within 2%.	
Repetition rate	Within 250 hertz.		
Risetime	Two microseconds or less.		
Duty Cycle	40% to 60%.		
Output Resistance			Approximately 10 kilohms.

EXTERNAL BLANKING

Sensitivity	+5 to +20 volts.	Blanking signal amplified and connected to unblanking deflection plate. Does not provide intensity modulation.
Input Coupling	DC (direct) coupled.	
Usable Frequency Range	DC to 100 kilohertz.	
Maximum Input Voltage		150 volts DC + peak AC.
Input Resistance at DC		Approximately 100 kilohms.

POWER SUPPLY

Characteristic	Performance Requirement	Operational Information
AC Operation Line voltage	115 volts nominal or 230 volts nominal.	Instrument can be converted between nominal line voltages with pin connectors on the Battery Charger circuit board.
Operating Range (AC, RMS) 115 volts nominal	90 to 136 volts	
230 volts nominal	180 to 272 volts	
Line frequency		48 to 440 hertz.
Maximum power consumption		14 watts at 115 volts AC; six-division four meghertz signal displayed, full intensity, full charge rate.
DC Operation Voltage range (DC)	6 to 16 volts	Power consumption is relatively independent of applied DC voltage.
Maximum power consumption		4.5 watts; six-division four megahertz signal displayed, full intensity.
Typical power consumption at normal intensity		1.6 watts with calibrator signal applied.
Battery Operation Batteries	Six size C nickel-cadmium cells.	
Charge time (Power Pack switch set to FULL CHG)		At least 16 hours.
Operating time (batteries charged at +20°C to 25°C, operated at +20°C to +30°C) 10 microamperes, or less, cathode current (low intensity)	Calibrator waveform displayed, 7 hours. Six-division four megahertz signal displayed, 4 hours.	
300 microamperes cathode current (full intensity)	Calibrator waveform displayed 4.4 hours. Six-division four megahertz signal displayed, 3 hours.	

Typical charge capacity (+20°C to +25°C charge-discharge reference) Charge temperature		Discharge temperature —15°C	 +20°C to +25°C	 +55°C
0°C		40%	60%	50%
+20°C to +25°C		65%	100%	85%
+40°C		40%	65%	55%

CATHODE-RAY TUBE (CRT)

Characteristic	Performance Requirement	Operational Information
Tube Type		Sony/Tektronix T3230-31-1 rectangular.
Phosphor		P31 standard. Others available on special order.

CATHODE-RAY TUBE (CRT) *(cont)*

Characteristic	Performance Requirement	Operational Information
Accelerating Potential		Approximately two kilovolts.
Graticule		
Type	Non-illuminated internal.	
Area	Six divisions vertical by 10 divisions horizontal. Each division equals 0.25 inch.	
Resolution		
Vertical		At least 15 lines in one division.
Horizontal		At least 15 lines in one division.
Geometry	Within 0.1 division.	Internally adjustable with Geom adjustment.
Unblanking	Deflection-type, DC coupled.	

ENVIRONMENTAL CHARACTERISTICS

The following environmental test limits apply when tested in accordance with the recommended test procedure. This instrument will meet the electrical performance requirements given in this section following environmental test. Complete details on environmental test procedures, including *failure criteria, etc., may be obtained from Tektronix, Inc.* Contact your local Tektronix Field office or representative.

Characteristic	Performance Requirement	Supplemental Information
Temperature		
Operating	—15°C to +55°C	
Charging	0°C to +40C	
Non-operating		
With Batteries	—40° to +60° C	
Without Batteries	—55° to +75° C	
Altitude		
Operating	30,000 feet maximum.	Maximum allowable ambient temperature decreases 1°C/1000 feet increase in altitude between 15,000 and 30,000 feet.
Non-operating (storage)	Tested to 50,000 feet.	
Humidity		
Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B.	Exclude freezing and vibration.
Vibration		
Operating and non operating	15 minutes along each of the three major axis at a total displacement of 0.025-inch peak to peak (4 g at 55 c/s) with frequency varied from 10-55-10 c/s in one minute cycles. Hold at 55 c/s for three minutes on each axis.	Instrument secured to vibration platform during test. Total vibration time, about 55 minutes. All major resonances must be above 55 c/s.
Shock		
Operating and non-operating	Two shocks of 30 g, one-half sine, 11-millisecond duration each direction along each major axis.	Guillotine-type shocks. Total of 12 shocks.
Electromagnetic Interference (EMI)	Test procedures and limits described in Mil-I-6181D and Mil-I-16910C.	Tested within electrically shielded enclosure with CRT mesh filter (Part No. 378-0596-00) and cabinet installed. Battery operation only, AC power cord and DC power input leads disconnected.
Radiated interference	Interference radiated from the instrument within the given test limits from 150 kilohertz to 1000 megahertz.	
Transportation	Meets National Safe Transit type of test when packaged as shipped by factory.	
Package vibration	One hour vibration slightly in excess of 1 g.	Package should just leave vibration surface.

ENVIRONMENTAL CHARACTERISTICS *(cont)*

Characteristic	Performance Requirement	Supplemental Information
Package drop	30-inch drop on any corner, edge or flat surface.	

MECHANICAL CHARACTERISTICS

Characteristic	Information
Construction Chassis	Aluminum alloy
Panel	Aluminum alloy with anodized finish.
Cabinet	Blue vinyl-coated aluminum.
Overall Dimensions (measured at maximum points) Height	4 1/5 inches (10.67 centimeters).
Width	8 1/2 inches (21.59 centimeters). 9 inches (22.86 centimeters) with AC power cord installed.
Length Handle extended	13 inches (33.02 centimeters).
Handle not extended	10$^{5}/_{8}$ inches (27.05 centimeters).

MECHANICAL CHARACTERISITCS *(cont)*

Net Weight	Approximately 6$^{3}/_{4}$ pounds 3.06 kilograms) without accessories.
Connectors VERT INPUT and EXT TRIG OR HORIZ INPUT	BNC
CAL OUT, EXT BLANK and EXT DC POWER	Banana jack.
AC POWER	Special three-pin connector compatible with the furnished AC power cord.

STANDARD ACCESSORIES

Standard accessories supplied with the Type 323 are listed on the last pullout page at the rear of this manual. For optional accessories available for use with this instrument, see the current Tektronix, Inc. catalog.

SECTION 2
OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

NOTE

Read the precautions contained in the First-Time Operation Procedure before operating the Type 323 Oscilloscope.

Introduction:

The following information is contained in this section:

- Explanation of exterior controls, connectors and indicators
- Accessories
- Power Pack Operating Procedure
- First-Time Operation
- Operator's Check and Adjustment Procedure
- Signal Transporting Methods
- Probe Adjustment
- Miscellaneous Operating Hints
- Glossary of Terms

Abreviations and symbols used in this manual are explained at the beginning of Section 7, Electrical Parts List.

EXPLANATION OF EXTERIOR CONTROLS, CONNECTORS AND INDICATORS

The following controls, connectors and indicators are contained on, or are accessible through the exterior surfaces of the Type 323 Oscilloscope, and are intended to be used during routine oscilloscope operation. All other controls are contained inside the covers and should be moved only during instrument calibration. The names of all Type 323 controls, connectors and indicators are written in capital letters wherever they appear in the manual. Specifications regarding the controls can be found in Section 1, Specification.

Handle — 320° rotation. Detents hold the handle in any one of the numerous positions throughout travel arc. Detents automatically unlock in response to rotary pressure on handle.

Front Panel

POWER — 2 position slide switch. Interrupts or completes power circuit between Power Pack and remaining oscilloscope circuitry. Does not affect battery charging circuitry.

LOW BATT — Indicator lamp. During "battery only" operation, flashes to indicate that batteries must be recharged before operation is continued. If the batteries become sufficently low, the Oscilloscope will stop operating and the lamp will stop flashing. Leaving the POWER switch ON after the batteries have reached this low state may damage the rechargeable cells. This "low charge" condition can be differentiated from equipment failure by applying AC power for a few minutes with the Power Pack switch at FULL CHG. Then disconnect the AC power and check for Oscilloscope and LOW BATT lamp operation. Flashing during EXT DC operation indicates that the power input is below 6.25 V. (Satisfactory operation can be obtained from external DC sources which are as low as 6 V.)

Vertical Controls

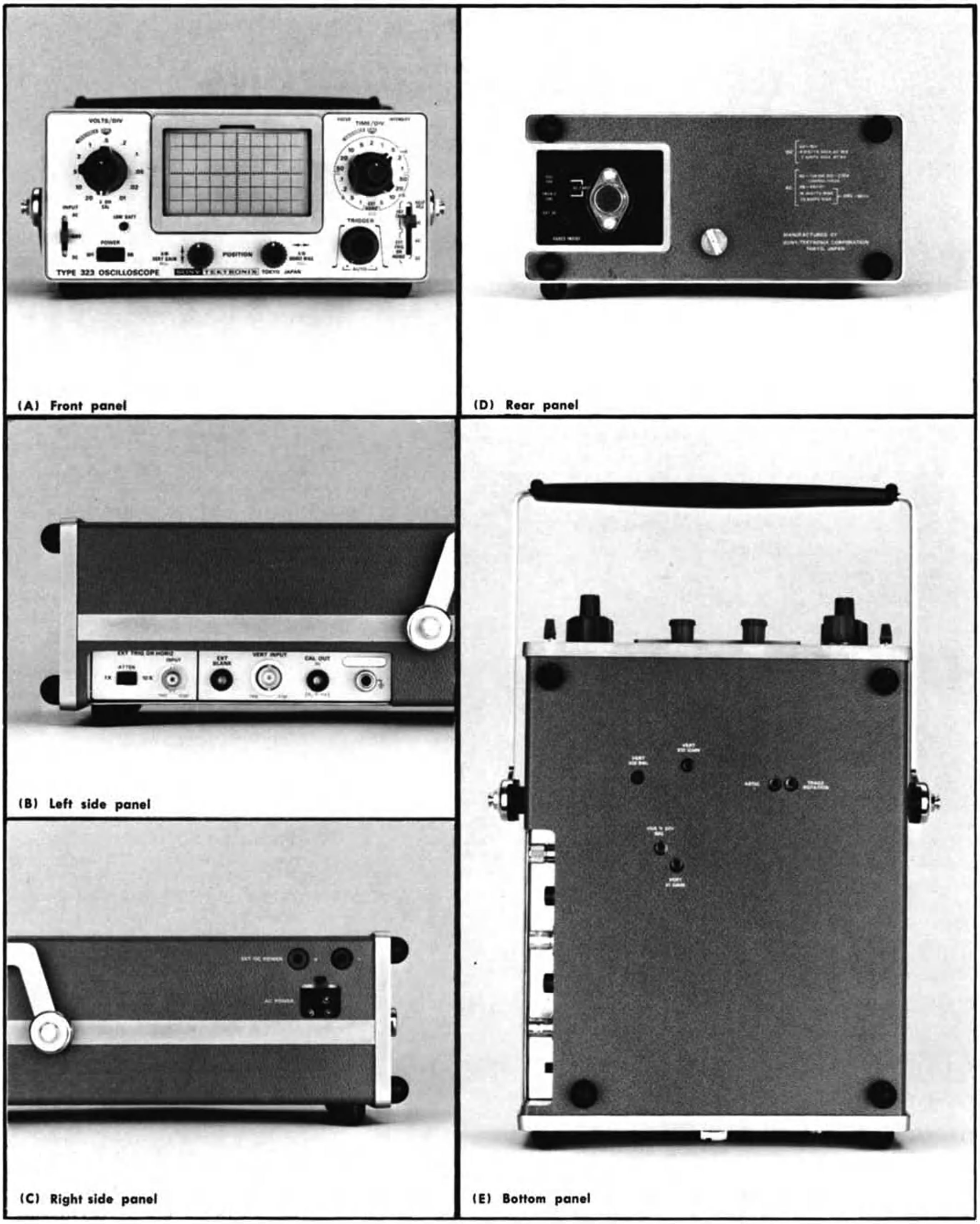
VOLTS/DIV — Rotary Switch. Selects calibrated vertical deflection factors from .01 VOLTS/DIV to 20 VOLTS/DIV. Value indicated applies only when VARIABLE (VOLTS/DIV) is at CAL position and ×10 VERT GAIN is pushed in. When rotated counterclockwise to 5 DIV CAL, it selects a 5 division reference square wave signal for calibration purposes.

VARIABLE — Potentiometer. Normally set to CAL position. Can be varied to select any deflection factor between the value selected by the VOLTS/DIV switch-×10 VERT GAIN combination and at least 2.5 times that value. Any deflection factor between .001 VOLTS/DIV and 50 VOLTS/DIV can thus be selected.

INPUT — 3-position lever switch. Selects the vertical signal input coupling method as follows:

- AC — AC signals; 2 Hz to 4 MHz at —3 dB limits
- GND — Grounds the amplifier input
- DC — DC to 4 MHz at —3 dB limits (Upper limit decreases to 2.75 MHz when ×10 VERT GAIN is employed.)

In addition, the INPUT control provides a precharge-discharge circuit for the coupling capacitor. The input coupling capacitor charges to the DC level of the input signal in the GND position, and discharges in the DC position.



(A) Front panel

(D) Rear panel

(B) Left side panel

(C) Right side panel

(E) Bottom panel

Fig. 2-1. External controls, connectors and indicators.

POSITION — Potentiometer. Sets the trace vertical DC reference position. Determines the no-signal vertical position of the CRT beam by setting the DC voltage applied to the vertical deflection plates.

×10 VERT GAIN — A slide switch attached to the Vertical POSITION shaft. It increases vertical gain by a factor of 10 when pulled out. (The vertical deflection factor selected by the VOLTS/DIV-VARIABLE combination is effectively divided by 10 when this control is pulled out.) A yellow band around the switch shaft becomes visible to indicate that ×10 VERT GAIN is in effect.

Horizontal Controls

TIME/DIV — Rotary switch. Selects calibrated sweep rates from 5 μS/DIV to 1 S/DIV. Value indicated only applies when VARIABLE (TIME/DIV) is set at CAL and the ×10 HORIZ MAG is pushed in. At EXT HORIZ position it permits horizontal trace deflection as a result of a horizontal input signal, the EXT TRIG OR HORIZ ATTEN control setting, and the horizontal amplifier deflection factor. The approximate EXT HORIZ deflection factor is 0.25 V/div and changes to about .025 V/div when the ×10 HORIZ MAG knob is pulled out. These values can be increased 10 times by using the VAR (EXT HORIZ) control.

VARIABLE — Potentiometer. Can be varied to select any sweep rate between the value selected by the TIME/DIV switch-×10 HORIZ MAG combination and 40% off that value. Any sweep rate between .5 μS/DIV and more than 2.5 S/DIV can thus be selected. When at CAL position it provides calibrated sweep rates as selected by the TIME/DIV—×10 HORIZ MAG combination.

VAR (EXT HORIZ) — Potentiometer connected to same control knob as VARIABLE (TIME/DIV). With EXT HORIZ selected by the TIME/DIV switch, the VAR control can vary the external horizontal deflection factor from approximately 0.25 V/div to 2.5 V/div with the EXT TRIG OR HORIZ ATTEN switch in the 1× position and the ×10 HORIZ MAG knob pushed in. Placing the EXT TRIG OR HORIZ ATTEN switch to the 10× position increases these values by a factor of ten; pulling the ×10 HORIZ GAIN control out decreases the values by a factor of 10.

POSITION — Potentiometer. Sets the starting point of the horizontal sweep. When the TIME/DIV switch is at the EXT HORIZ position, it determines the horizontal position of the CRT beam by setting the DC voltage applied to the CRT horizontal deflection plates. Coarse and fine control potentiometers with a 10:1 ratio are connected to the POSITION shaft. The fine control has 30° of rotation independent of the coarse control. This back-lash arrangement permits the use of a single knob for coarse and fine adjustments, with the coarse adjustment during ×1 HORIZ MAG being equal to the fine adjustment during ×10 HORIZ MAG operation.

×10 HORIZ MAG — A slide switch attached to the Horizontal POSITION shaft. When it is pulled out, the horizontal sweep rate selected by the TIME/DIV-VARIABLE combination is effectively divided by 10. The 1 division of trace that previously straddled the graticule vertical center is thus expanded to cover the full length of the graticule. Any 1 division of the sweep can be displayed as a 10 division trace by combined use of the Horizontal POSITION control and the ×10 HORIZ MAG.

With the TIME/DIV switch at EXT HORIZ position, pulling the ×10 HORIZ MAG out increases the deflection caused by a HORIZ INPUT signal by a factor of 10. A yellow band around the switch shaft becomes visible to indicate that ×10 HORIZ MAG is in effect.

TRIGGER — A combination of rotary switch wafers and a center tapped potentiometer. Selects positive (+) slope triggering level when the knob's indicator spot is to the left of the knob's vertical center; selects negative (—) slope triggering level when the knob's indicator spot is to the right of the knob's vertical center. The indicator spot versus the plus and minus waveform slopes (which appear alongside the TRIGGER knob) indicates the approximate point on the waveform at which triggering occurs. When the control is at the counterclockwise (+ AUTO) or clockwise (— AUTO) limit, a baseline of relatively constant brightness is automatically provided during the absence of triggering signals. Input signals whose frequencies are higher than that of the automatic base line generator override it to trigger the baseline.

Trig/Horiz Coupling Switch — Four position lever switch; selects the source and type of triggering; also selects EXT HORIZ INPUT coupling mode.

INT TRIG ACLF REJ — Selects Internal AC triggering signal; the triggering circuit is de-sensitized to signals below about 30 kHz.

AC — Selects Internal AC triggering signal.

EXT TRIG OR HORIZ — Refers to External Horizontal input coupling when TIME/DIV is in EXT HORIZ position; refers to External Trigger coupling mode in all other positions of TIME/DIV switch.

AC — Selects external AC triggering signal.

DC — Extends triggering limit to DC so that a trigger will be generated for even the slowest change of signal through the selected trigger level. Automatically reverts to AC-coupling during AUTO Trigger operation.

NOTE

The Trig/Horiz Coupling switch must be in an EXT TRIG OR HORIZ position when EXT HORIZ operation is selected by the TIME/DIV switch. Leaving it in either of the INT TRIG positions when EXT HORIZ operation is selected applies the vertical signal to both the vertical and horizontal axis, creating a meaningless display.

Top Panel

FOCUS — Thumbwheel accessible through top panel. Adjusts CRT electron beam for optimum display sharpness.

INTENSITY — Thumbwheel accessible through top panel. Controls the brightness of the CRT display.

IMPORTANT

Battery operating time varies inversely with CRT trace intensity. Use the minimum brightness necessary for good viewing.

Left Side Panel

EXT TRIG OR HORIZ

ATTEN — Two position slide switch. When in 10× position it attenuates the EXT TRIG OR HORIZ INPUT signal by a factor of 10.

INPUT — BNC connector with 62 pF input capacitance. Capacitance changes slightly when ATTEN is at 10×. Has 1 MΩ input resistance whenever the Trig/Horiz coupling switch is at DC or when the EXT TRIG OR HORIZ ATTEN switch is at 10×. Maximum allowable input is 500 V DC + peak AC.

EXT BLANK — Banana jack which is DC coupled to the unblanking circuits. Positive signals between 5 and 20 volts cause blanking of CRT trace. 150 V DC + peak AC maximum allowable input signal.

VERT INPUT — BNC connector with 1 MΩ and 47 pF input impedance. 500 V DC + peak AC maximum allowable input.

IMPORTANT

Battery operating time varies inversely with input signal frequency and the display amplitude.

CAL OUT — Banana jack which makes the vertical amplifier's 0.5 V square wave signal available for monitoring or external use, such as probe calibration. Has approximately 10 kΩ source impedance. External load will decrease its output in proportion to the load.

Ground — Banana jack type binding post connected to chassis ground.

Right Side Panel

EXT DC POWER — Banana jack type input connectors (red +, black —). Accepts external DC power source from 6 to 16 V for Oscilloscope operation. Does not charge battery pack. Negative input jack is connected to case ground.

CAUTION

Reverse polarities applied to the EXT DC POWER connectors will blow the high voltage fuse.

AC POWER — 3 terminal line plug connector. Accepts 90 to 136 V AC, 48 to 440 Hz (or 180 to 272 V AC, 48 to 440 Hz, if wired for 230 V AC nominal input voltage) for Oscilloscope operation and battery charging. Batteries are on charge whenever power is applied, regardless of Oscilloscope switch positions.

Rear Panel

Power Pack Switch — 3 position slide switch which allows selection of the power source and the battery charge rate, as follows:

FULL CHG — AC power applied to the line connector charges the batteries at the maximum rate (full charge in 16 hours), and supplies power for Oscilloscope operation. If no AC is present, internal battery power is applied to the POWER switch for Oscilloscope operation.

TRICKLE CHG — Same conditions exist as for FULL CHG, except that the charging rate is reduced. Counteracts self-discharge, thus keeping battery fully charged.

EXT DC — Permits operation from a DC source of between 6 and 16 volts. DC input does not recharge the internal battery pack.

IMPORTANT

The oscilloscope will not operate in any power mode if the switch is in the EXT DC position and no external DC power is applied.

Fuses — Located internally. See Maintenance section.

Cover Securing Screw — Located near bottom-middle of rear panel. Counterclockwise rotation disconnects cover from oscilloscope chassis, allowing chassis to be removed through front of cover assembly.

Bottom Panel

The following screwdriver adjustments are accessible through holes in the bottom panel. The procedure for adjusting them is given under Operator's Adjustment Procedure, and can also be found in the Performance Check and in the Calibration Procedure.

TRACE ROTATION	Adjusts the horizontal sweep path to parallel horizontal graticule lines.
ASTIG	Astigmatism. Adjusts for optimum sharpness of vertical and horizontal lines at the same setting of the FOCUS control.
VERT ×1 GAIN	Adjusts to provide calibrated gain factors with ×10 VERT GAIN pushed in.
VERT ×10 GAIN	Adjusts (after VERT ×1 GAIN has been adjusted) to provide calibrated gain factors with ×10 VERT GAIN pulled out.
VERT ×10 BAL	Adjusts for no trace shift accompanying switching between ×1 and ×10 positions of ×10 VERT GAIN control, under no-signal conditions.
VAR V/DIV BAL	Adjusts for no trace shift during rotation of VARIABLE (VOLTS/DIV) knob, under no-signal conditions.

ACCESSORIES

Standard accessories which are included with the Type 323 Oscilloscope are listed near the rear of this manual. Although most items require no explanation, the following information should be helpful in their use:

CRT Face Shield, Clear. This is not listed as a standard accessory, but is installed in the bezel plate recess prior to shipment from the factory. It provides protection for the CRT face, and also acts as protection against the possibility of implosion. It should always be kept installed except when the CRT light filter is in use. To install, insert the lower edge into the groove at the bottom of the bezel. Push it down against its spring until the top can be slid past the top of the bezel. The spring will push it into the groove at the top of the bezel and hold it in place.

CRT Light Filter. The filter performs the same function as the clear shield, and improves CRT viewing in brightly lighted locations. (External light is attenuated when it passes through the filter in both directions. The presentation receives only 50% as much attenuation because it passes through the filter in only one direction in reaching the viewer's eye.)

Viewing Hood. To install, attach the top first, inserting the key into the groove in the top of the bezel.

P6049 Probe. This probe contains a right angle adapter which contains a compensation adjustment. See the explanation later in this section, or in the P6049 Probe manual.

Patch Cord. This cord can be used to connect any banana jack to a BNC-female connector; for example, connecting the Type 323 Oscilloscope CAL OUT jack to the TRIG OR HORIZ INPUT or the VERT INPUT connectors.

3 to 2-Wire Adapter. Grounding is not provided through the AC power source when the adapter is in use. A separate grounding connection must be used.

Panel Cover. A friction fit keeps this cover over the front panel during storage or transporting. The cover can be placed over the rear of the Oscilloscope for storage when the Oscilloscope is in use. The recess in the cover accommodates the accessory pouch strap and should not be used as a finger grip for cover removal.

Accessory Pouch. This unit grips on the handle pivots and on the cover securing screw at the rear panel. It has sufficient capacity to hold the standard accessories, with the exception of the manuals and the Panel Cover.

Strap Assembly. The strap is designed to be snapped into place for transporting the Oscilloscope. It can be used to suspend the Oscilloscope in front of or alongside the operator during use. The handle can be extended between the operator and the Oscilloscope to obtain optimum viewing positions.

POWER PACK OPERATING PROCEDURE

General

The Power Pack contains internal batteries, a battery charger and a control switch. The switch determines the source of power for Oscilloscope operation, and selects one of two battery charging rates. The correct charge rate is applied to the batteries whenever AC power is applied, whether the Oscilloscope is on or off. It should be noted that the battery cannot take a charge when it is at a temperature below 0°C (32°F); nor should it be subjected to a charge when its temperature is above 40°C (104°F).

When fully charged, the battery pack can supply the 1½ watts required by the Oscilloscope during average operating conditions for approximately 7 hours. Actual operating time varies inversely with sweep rate, the display signal frequency and amplitude, the display intensity, and the ambient temperature during cell charging.

The Nickel-Cadmium (NiCd) cells have been selected to give the best high temperature performance available. Each cell has been rigidly inspected, received an ampere-hour test, and has met or exceeded the minimum ampere-hour storage time requirements. Maximum operating life can be obtained by adhering to the following recommendations regarding NiCd cells in general, and their use in the Type 323 Oscilloscope.

Operation

The Oscilloscope can be operated from the internal battery, from either 90 to 136 V AC or 180 to 272 V AC (48 to 440 Hz), or from an external DC source of between 6 and 16 volts. Battery charging takes place whenever AC is applied. The rate of charge is determined by the Power Pack switch which is accessible at the rear of the Oscilloscope.

Internal Battery-Powered Operation

Placing the Power Pack switch to either TRICKLE CHG or FULL CHG connects the internal battery to the front-panel POWER switch, permitting internal battery-powered operation. Internal battery-powered operation is not possible with the Power Pack switch at EXT DC.

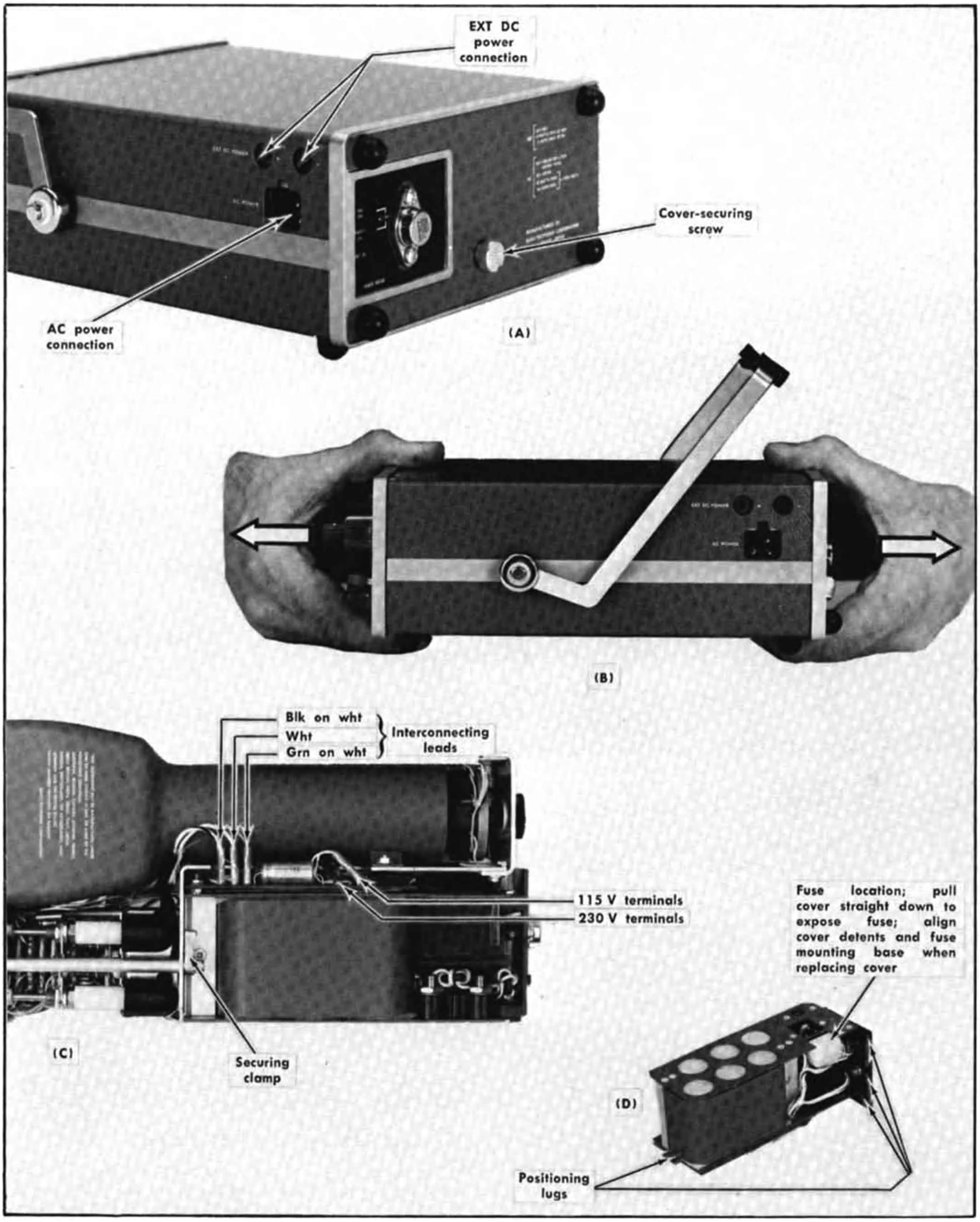


Fig. 2-2. Power Pack removal.

Internal battery-powered operation should not be continued after the LOW BATT lamp starts flashing. The battery should immediately be put on charge at a FULL CHG rate to avoid the possibility of individual cells becoming reverse-charged. Operation can continue during recharge.

If internal battery-powered operation is inadvertently continued after the LOW BATT lamp starts flashing, eventually the trace will disappear and the light will stop flashing; damage to the battery NiCd cells may result.

External DC-Powered Operation

The Oscilloscope can be powered by an external DC source of between 6 and 16 volts. The external DC power source must be connected to the EXT DC POWER connectors on the right side of the Oscilloscope, and the Power Pack switch placed at EXT DC. The external DC source will not charge the internal battery.

CAUTION

Do not apply reverse polarity to the EXT DC POWER connectors. It will blow the high voltage fuse.

AC-Powered Operation

An AC source can be used to power the Oscilloscope when the Power Pack switch is at either TRICKLE CHG or FULL CHG. In addition, the battery charges at the indicated rate whenever AC is applied, regardless of the status of the Oscilloscope POWER switch. It may be noted that if the Power Pack switch is left in EXT DC when AC is applied, the internal battery will charge at the full charge rate, even though AC or internal battery-powered Oscilloscope operation is interrupted.

Either 115 or 230 V nominal AC power may be used, but slip-on connectors at the Power Pack must be connected in accordance with the voltage to be used. The internal fuse must also be changed whenever the AC voltage range is changed. Spare fuses for 115 V and 230 V operation are contained inside the Oscilloscope adjacent to the side control panel. The following procedure explains the Power Pack removal, connection changes, and Power Pack replacement.

Power Pack Removal. Disconnect all cables from the Oscilloscope and place the Oscilloscope Power Pack switch at EXT DC.

Remove the cover-securing screw from the back of the case. See Fig. 2-2(A).

Grip the front edge of the Oscilloscope with one hand, and the cover assembly with the other hand as shown in Fig. 2-2(B). Pull the cover assembly off the chassis, maintaining a firm grip on the front of the chassis.

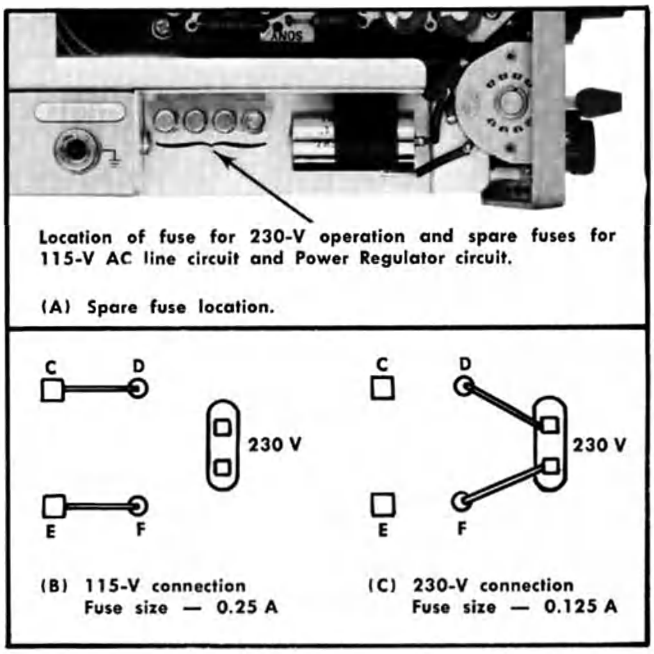
Set the Oscilloscope chassis down on a flat surface. Disconnect the three interconnecting leads and release the Power Pack securing clamp. See Fig. 2-2(C).

Move the Power Pack approximately 1/4 inch toward the rear of the chassis to release the positioning lugs. Then remove the Pack sideways from its mounting area. Use caution to avoid striking transformer wires or the circuit board against the Oscilloscope chassis.

WARNNG

The battery used in the Power Pack is capable of delivering a large amount of energy in a short time. Rings, watch bands, or other metallic items which short-circuit the battery can rapidly become hot enough to cause severe burns. Keeping the Power Pack switch at EXT DC minimizes the number of points in the circuitry to which the battery voltage is applied.

115/230 V Connection Changes. Fig. 2-2(C) illustrates the location of the jumper wires and of the fuse. The two possible circuit arrangements, accompanying fuse sizes and the locations of spare fuses are indicated in Fig. 2-3. Reinstall the insulated tubing over the unused AC terminals.



Location of fuse for 230-V operation and spare fuses for 115-V AC line circuit and Power Regulator circuit.

(A) Spare fuse location.

(B) 115-V connection Fuse size — 0.25 A

(C) 230-V connection Fuse size — 0.125 A

Fig. 2-3. Connections for 115 V and 230 V AC operation.

Power Pack Replacement. Replace the Power Pack by reversing the removal procedure, insuring that the wire color code agrees with that written on the terminal mounting. See Fig. 2-2(C). Avoid pinching of fingers at the front panel when the Oscilloscope cover is replaced.

IMPORTANT

The Oscilloscope will not operate from the internal battery or from an AC source if the Power Pack switch is left in the EXT DC position. However, it may be noted that if the switch is left in this position and AC is applied, the battery will charge at a full-charge rate.

Charging

Although the battery contained in the Type 323 Oscilloscope is charged before packaging, it should be recharged for 16 hours at a FULL CHG rate when put into service.

The charging characteristics of NiCd cells vary with the temperature existing during charge time. A cell which obtained a full charge in a given thermal environment will deliver more energy than an identical cell which was fully charged under higher temperature conditions. Cells can be expected to become warmer as the fully charged point is approached, despite ambient conditions. This is a natural phenomenon which has little effect upon the energy which the cell can retain, since the amount of total charge is dependent principally upon the cell temperature during the first three-quarters to seven-eighths of a full-charge cycle.

The Power Pack is normally put on charge without removing it from the Oscilloscope. However, it can be charged while it is outside of the Oscilloscope. This permits better air circulation around the pack, thus maintaining a cooler battery temperature. Slightly more energy will therefore be stored in the cells, providing a little longer battery-operated cycle. In addition, the ability to be charged independent of the Oscilloscope permits continuous internal battery powered use if a second Power Pack is obtained. Less than 1 minute is required for exchanging Power Packs.

If NiCd cells become reverse charged, their ability to be re-charged can be impaired or destroyed. The battery charger is designed to prevent accidental application of reverse charging current. However, an unbalance between cells in a battery can develop during operation or during partial charging. It is possible for the unbalance to become so great that during discharge the weakest cells completely lose their charge and then become reverse-charged by the current from the strong cells.

Considering that the battery initially consists of equal-quality cells, the obvious method for avoiding reverse-charging of an individual cell is to keep the cells equally charged. This can be done by completing a full-charge cycle, which consists of applying FULL CHG current for 16 hours. The full charge cycle should be completed in preference to a partial charge cycle whenever possible. In addition, approximately once a month or every 15 charge-discharge cycles (whichever occurs first) the battery should be charged at a FULL CHG rate for approximately 24 hours.

Once the battery has been fully charged, the Power Pack switch should be placed at TRICKLE CHG and the AC power cord should be left connected. This will keep the battery in a fully charged condition.

Although partial recharging of NiCd batteries is not recommended as a common practice, occasional partial recharges can be tolerated. About 30 to 45 minutes of operating time can be expected as a result of a 1 hour charge period.

The energy-storing capability of the NiCd cells decreases gradually with age and the number of charge-discharge cycles. However, the battery should provide a useful operating life well in excess of several hundred charge-discharge cycles.

Storage

NiCd cells can be stored either fully or partially charged. Storage temperature may be between —40° and +120° F, but the self-discharge rate increases with temperature. At 70° F, a fully charged cell can be expected to self-discharge down to about 50% in three months. Cells and Power Packs which are not in use should therefore be given a full recharge at least every three to six months to avoid their becoming reverse-charged.

Maintenance and Repair

Additional data regarding maintenance and repair of the Power Pack and the NiCd cells can be found in the Maintenance section of this manual.

FIRST TIME OPERATION

This first time operation is designed to obtain a trace and provide familiarization with the Oscilloscope controls and responses. A control setup chart is provided in Fig. 2-4. It can be duplicated as a convenient method of recording specific setups in conjunction with Oscilloscope familiarization and use.

CAUTION

1. Internal battery-powered operation should not be continued for long periods after the LOW BATT lamp starts flashing. Damage to the NiCd battery may result. If the battery becomes sufficiently discharged, the trace will disappear and the light will cease flashing. The battery should then be recharged to avoid the possibility of individual cells becoming reverse-charged. Operation can continue during recharging.

2. Always operate within the Oscilloscope's allowable input values, which are as follows:

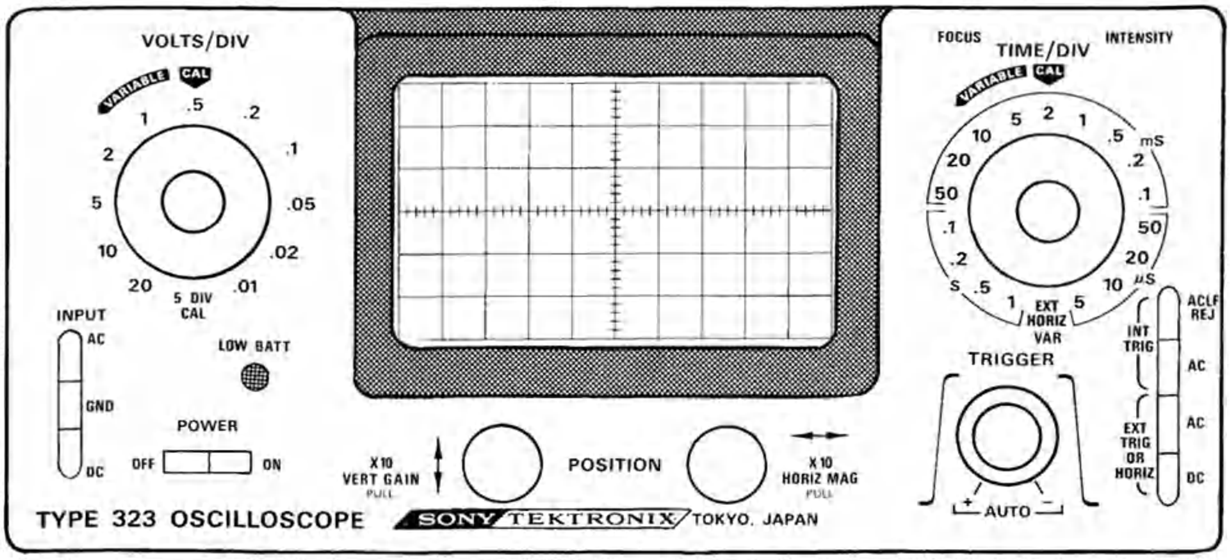
Power Source-AC	48 to 440 Hz
Wired for 115 V operation:	90 to 136 V
Wired for 230 V operation:	180 to 272 V
Power Source-DC	6 to 16 V
VERT INPUT	500 V DC + peak AC
EXT TRIG OR HORIZ INPUT	300 V DC + peak AC
EXT BLANK	150 V DC + peak AC

WARNING

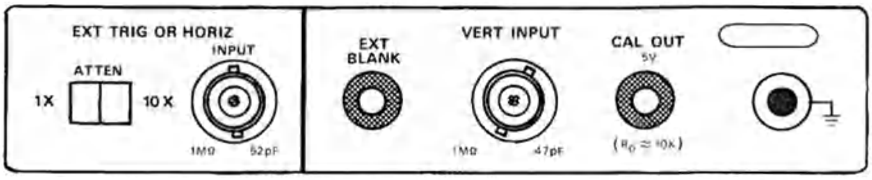
Unless the Type 323 Oscilloscope is connected to a common ground, its metallic parts will be elevated to the signal potential to which it is connected. The ground loop must always be completed for normal operation of the Type 323 Oscilloscope. Unreliable results and unsafe conditions will otherwise exist. Connect a lead between Oscilloscope ground and equipment ground before connecting the Oscilloscope inputs to equipment test points. Do not remove the ground lead until all other connections are removed.

1. Preset the controls as follows:

VOLTS/DIV	5 DIV CAL
VARIABLE (VOLTS/DIV)	CAL
INPUT	GND
×10 VERT GAIN	In



Front panel



Left side panel

Fig. 2-4. Control setup chart.

POSITION (Vertical)	Midrange
×10 HORIZ MAG	In
POSITION (Horizontal)	Midrange
TIME/DIV	.5 ms
VARIABLE (TIME/DIV)	CAL
TRIGGER	+ AUTO
Trigger Coupling	INT TRIG AC
FOCUS	Midrange
INTENSITY	Midrange
Power Pack Switch	TRICKLE CHG

2. Connect the AC power cord (standard accessory) between the Oscilloscope and an appropriate AC source, if available. Place the Power Pack Switch at TRICKLE CHG and turn the POWER switch ON. Check that the LOW BATT indicator does not flash.

3. Observe that a square wave appears on the face of the cathode ray tube (CRT). Readjust INTENSITY and FOCUS for optimum presentation. Use the minimum CRT intensity necessary for good viewing to conserve battery power.

Operating the Vertical Controls

4. Adjust the vertical POSITION control to center the square wave; observe 5 divisions (±0.15 division) display amplitude.

5. Adjust the horizontal POSITION control to start the trace at the left (0-div) vertical graticule line.

6. Gradually rotate the VARIABLE (VOLTS/DIV) knob ccw from its CAL position. Observe that the square wave presentation simultaneously decreases to an amplitude of 2 divisions or less at the counterclockwise limit. Return the control to the CAL position.

7. Pull the ×10 VERT GAIN out. Note that there is no change in the calibration signal display amplitude. The cal signal is reduced by a factor of ten to compensate for

the increase in gain when the ×10 VERT GAIN control is out. Return the ×10 VERT GAIN control to its in position.

8. Set the VOLTS/DIV switch to .02. Observe that the 5 DIV CAL square wave is replaced by a horizontal trace which appears approximately $2\frac{1}{2}$ divisions below graticule center. Reset the trace to graticule center. This will be used as the DC reference position. (The DC reference position can be arbitrarily established anywhere on the CRT by adjusting the vertical POSITION control while the probe tip is grounded or the INPUT switch is at GND position.)

9. At the side panel, connect the Type P6049 probe cable to the VERT INPUT connector. Connect the probe tip to the 0.5 V square-wave signal at the CAL OUT jack.

10. Switch the INPUT control to DC. Observe that a square wave $2\frac{1}{2}$ divisions in amplitude appears on the CRT. The instantaneous voltage at the top and bottom of the square wave can be measured as follows:

Determine the number of divisions of separation between the previously established DC reference and the top of the square wave. Multiply by the value of the VOLTS/DIV knob setting and the probe attenuation factor. The position of the top of the trace is above the DC reference indicating a positive voltage. The bottom of the trace appears at the DC reference point. The trace is operating between 0 and +0.5 V DC. See Fig. 2-5(A) and (B).

11. Switch the INPUT control to AC. Note that removal of the DC component causes the trace to shift downward, centering around the previously established trace DC reference position. See Fig. 2-5(C).

12. Compute the signal amplitude. .02 VOLTS/DIV deflection factor multiplied by the 10× probe attenuation factor and by the $2\frac{1}{2}$ divisions of deflection equals 0.5 V signal amplitude. Note that this equals the difference between the waveform's DC voltage limits found during DC measurement in step 10, although the waveform's DC operating level does not appear.

13. Set the VOLTS/DIV control to 0.1. Note that the display amplitude reduces to $\frac{1}{2}$ division. Again calculate the input signal amplitude (0.5 V).

14. Pull the ×10 VERT GAIN control out. Note that the display amplitude increases to 5 divisions. Compute the display amplitude by using the following procedure:

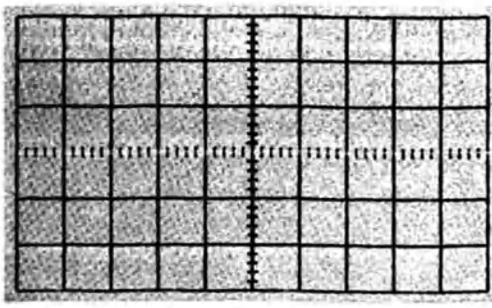
Divide the VOLTS/DIV setting by 10 to determine the vertical deflection factor with the ×10 VERT GAIN out.

Multiply this deflection factor by the number of divisions of deflection and the 10× probe factor to determine the input signal amplitude (0.5 V).

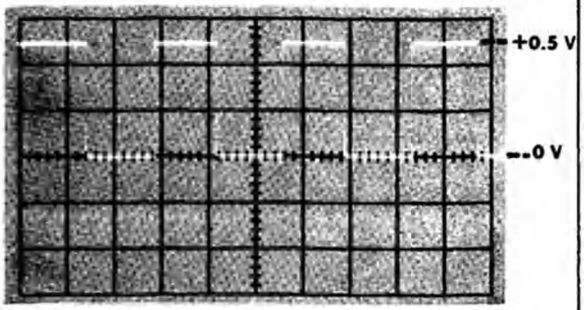
(The 10X probe attenuation is effectively compensated for by the ×10 Vert Gain switch; under this condition, the vertical deflection factor reads directly from the VOLTS/DIV control setting—5 div × .1 V/DIV = 0.5 V signal input.)

Operating the Horizontal Controls

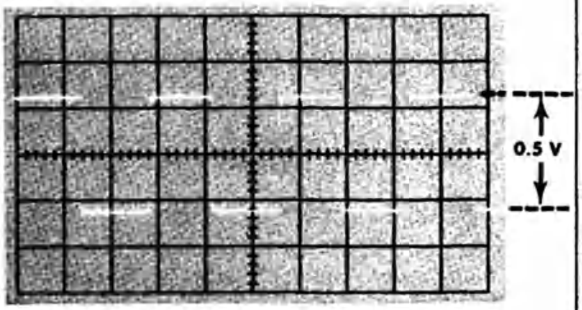
15. Calculate the square wave period time. Multiply the number of divisions per one cycle of square wave by the



(A) DC reference position set at graticule vertical center.



(B) 0.5 V square wave signal DC-coupled into vertical circuit. DC operating level and signal amplitude can be determined. Deflection Factor .2 VOLTS/DIV.



(C) Same signal, AC-coupled into vertical circuit. Note that signal DC operating level cannot be determined.

Fig. 2-5. DC versus AC input coupling.

TIME/DIV setting. Reset the vertical POSITION knob as necessary for convenient measurement. (Approximately 1.3 ms per cycle.) See Fig. 2-6.

16. Calculate the square-wave frequency by determining the reciprocal of the period time. (Approximately 750 Hz).

17. Switch the TIME/DIV control to 2 ms. Observe that approxiamtely $1\frac{1}{2}$ square waves per division are now being displayed. Calculate period time (approximately 1.3 ms) and frequency (approximately 750 Hz).

18. Pull the ×10 HORIZ MAG out. Observe that about 1 square wave per seven divisions is now being displayed. Calculate the period time and frequency. (It is still approximately 1.3 ms and 750 Hz respectively.)

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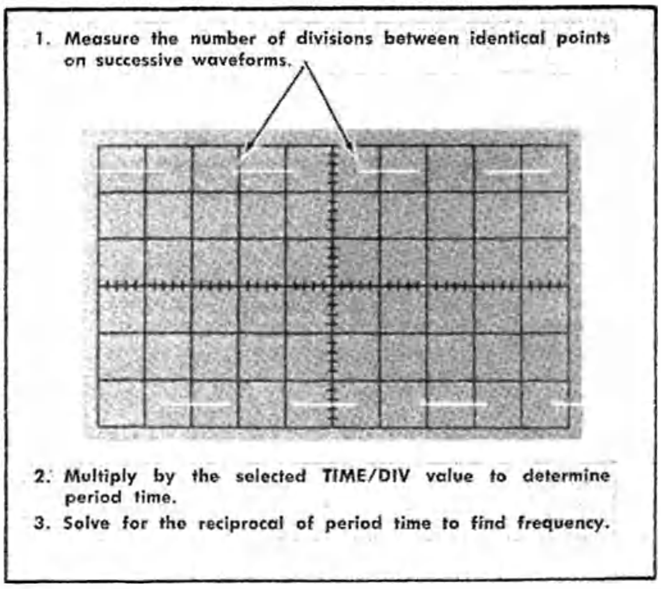


Fig. 2-6. Determining frequency.

19. Slowly rotate the Horizontal POSITION control. Note that an almost equal number of waveforms can be observed before and after the occurrence of the waveform which appeared when the ×10 HORIZ MAG was pulled out. This situation exists because the ×10 HORIZ MAG displays the 1 division of trace which straddles the graticule centerline during ×1 horizontal operation.

20. Rotate the VARIABLE (TIME/DIV) slowly ccw. Note that the resultant decrease in sweep speed causes more square waves to appear. With VARIABLE fully ccw, approximately 4 square wave appear. Return the VARIABLE control to CAL and the ×10 HORIZ MAG to in.

Operating the Trigger Controls

21. Note that the positive portion of the square wave is being displayed at the beginning of the trace. Switch the TRIGGER control to — AUTO and observe that the negative portion of the square wave is being displayed at the beginning of the trace. The + or — selection determines whether the horizontal sweep will be triggered by a positive-going (+) or a negative-going (—) signal. In the absence of a signal, AUTO provides a free-running time base of relatively constant brightness, regardless of the sweep rate.

22. Push the ×10 VERT GAIN control in and set the VOLTS/DIV knob to .05. Connect the P6049 Probe to the VERT INPUT connector. Then connect the probe tip and ground lead across the output of a low-frequency sine wave generator. Set the generator for a 2-V peak-to-peak, 60 Hz output. Observe a sine wave which is 4 divisions peak-to-peak. Note that the beginning of the waveform has a negative (decreasing) slope. See Fig. 2-7(A).

23. Rotate the TRIGGER control slowly counterclockwise from the — AUTO position. Note that as the control leaves the AUTO position, the trace disappears. As the control is moved further counterclockwise, a point is reached where the sweep is again triggered by the negative change in signal level. Continue the counterclockwise movement of the TRIGGER control and note that triggering occurs at progressively more positive points of the waveform. See Fig. 2-7(B). Continue the rotation through the control center position. The trace will disappear or become unstable, then reappear, being triggered by the positive change in signal level. See Fig. 2-7(C). Leave it in this position. (Either AUTO or manual trigger selection may be used in normal operation, as determined by the application and the operator's preference. It is suggested that AUTO be used in most applications, switching to manual when necessary to improve stability, increase the low-frequency triggering range, or to change the triggering point.)

24. Switch the Trig/Horiz Coupling lever to EXT TRIG OR HORIZ-AC. Note that the trace disappears. At the side panel, connect the 2 volt peak-to-peak sine wave signal to the EXT TRIG OR HORIZ INPUT connector. (Keep the P6049 Probe connected to the 2 volt peak-to-peak sine wave.) Note that a stabilized trace appears. Decrease the

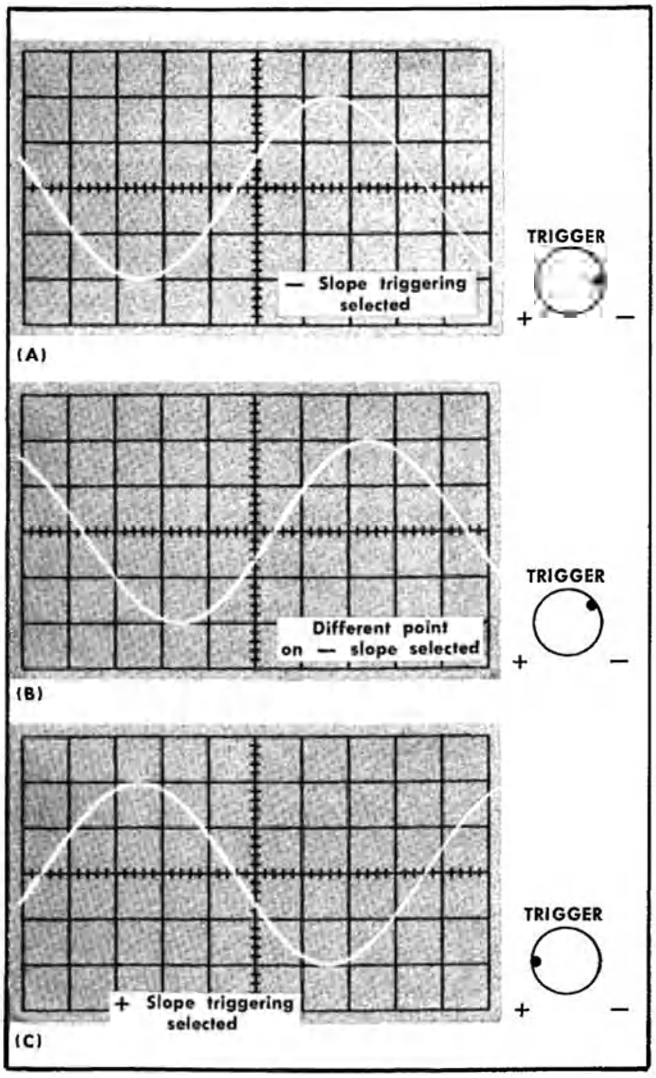


Fig. 2-7. Selection of triggering point.

generator frequency until the trace disappears and then note the frequency. (The triggering circuit half-power point occurs at approximately 16 Hz during AC-coupled operation.)

25. Switch the Trig/Horiz Coupling control to DC, and the TIME/DIV control to .2 mS. Note that the trace re-appears. Decrease the signal generator frequency to 2 Hz. Note that a stable trace remains. (Readjust the TRIGGER Level if necessary.) When DC coupling is selected and the TRIGGER control is not at AUTO, a trigger can be generated whenever the EXT TRIG OR HORIZ INPUT voltage passes through the DC value selected by the TRIGGER Level control, even though the transition is made very slowly. If the signal has a DC bias, the trigger point will be influenced by that bias.

26. Switch the TRIGGER control to + AUTO. Note that the trace becomes unstable. The trigger input becomes AC-coupled whenever the TRIGGER control is at AUTO, regardless of the setting of the Trig/Horiz Coupling lever. The 2 Hz signal frequency is too low to cause AC-coupled triggering to occur. Increase the generator frequency to 60 Hz and note that the display becomes stable, indicating that the sweep is again being triggered by the input signal.

27. Disconnect the signal from the EXT TRIG OR HORIZ INPUT connector. Switch the Trigger Coupling lever to INT TRIG ACLF REJ. Note that the trace is again unstable. Change the generator frequency to 10 kHz and note that the trace stabilizes. ACLF REJ greatly reduces circuit sensitivity to internal trigger signals of approximately 10 kHz and lower, to prevent low-frequency signals from randomly triggering the sweep while high frequency signals are being observed.

XY Operation

NOTE

Whenever the Type 323 Oscilloscope is operated in EXT HORIZ mode, the CRT is unblanked and no internal sweep is available. If no input signal is present at the vertical or horizontal input connector, a bright stationary dot will appear. It is recommended that the brightness be reduced to provide an intensity which is consistent with good viewing. Decreasing beam intensity will also increase battery-operating time.

28. Reconnect the signal generator output to the EXT TRIG OR HORIZ INPUT jack. Switch the TIME/DIV control to EXT HORIZ and the Trig/Horiz Coupling lever to EXT TRIG OR HORIZ-AC. The straight diagonal line rising as it progresses from left to right is indicative of in-phase conditions existing between the signals at the vertical and horizontal input connectors. The deflection along the vertical and horizontal coordinates is dependent upon the amplitude of the respective input signals and the deflection factors involved.

29. Rotate the EXT HORIZ VAR counterclockwise from CAL and note that as the horizontal gain decreases, the slope becomes greater. Return the EXT HORIZ VAR to CAL.

30. Switch the EXT TRIG OR HORIZ ATTEN to ×10. Observe that the horizontal deflection is reduced to 1/10 of its previous amount.

31. Reset controls as follows:

EXT TRIG OR HORIZ ATTEN	×1
VOLTS/DIV	5 DIV CAL
INPUT	GND
×10 VERT GAIN	in
×10 HORIZ MAG	in
TIME/DIV	.2 ms
TRIGGER	+ AUTO
Trigger Coupling	INT TRIG AC

Adjust the POSITION controls until the square wave again appears on the CRT.

32. Disconnect the cables from the VERT INPUT and EXT TRIG OR HORIZ INPUT connectors.

Power Supply Operation

33. Switch the Power Pack switch to FULL CHG. Note that no change occurs in the presentation.

34. Disconnect the AC source from the Oscilloscope. Again note that no change occurs in the presentation.

35. Connect the Oscilloscope to an external DC voltage of between 6 and 16 V, using two leads equipped with banana plugs. Make the proper polarity connections. Reverse connections will blow the high voltage fuse. Switch the Power Pack switch to EXT DC. Again, note that there is no apparent change.

36. Switch the POWER control off and the Power Pack switch to FULL CHG. Disconnect the Oscilloscope from the DC power source and reconnect the AC power input to an appropriate AC voltage supply. Retain this condition for 16 hours to obtain a full battery charge.

The First-Time Operation procedure has been completed. After 16 hours have elapsed, switch the Power Pack switch to TRICKLE CHG to maintain the fully charged battery condition.

OPERATOR'S CHECK AND ADJUSTMENT PROCEDURE

The following characteristics of the Type 323 Oscilloscope should be checked prior to each period of operation. Access to screwdriver adjustments are provided through the bottom panel to permit the operator to optimize the instrument's performance. Perform the checks and adjustments in the sequence provided to avoid interaction.

CAUTION

Use a loose fitting screwdriver to make the adjustments. Do not apply excessive force.

Preliminary Procedure

Set the Type 323 Oscilloscope controls as follows:

VOLTS/DIV	5 DIV CAL
INPUT	GND
×10 VERT GAIN	In
POSITION (Vertical)	Midrange
×10 HORIZ MAG	In
POSITION (Horizontal)	Midrange
TIME/DIV	1 mS
VARIABLE (TIME/DIV)	CAL
TRIGGER	+ AUTO
Trigger Coupling	INT TRIG AC
POWER	ON
INTENSITY	Optimum

Set the Oscilloscope on its left side to allow access to the bottom adjustments.

ASTIG

Adjust the VARIABLE (VOLTS/DIV) to obtain 3 divisions of vertical amplitude. Center the trace as shown in Fig. 2-8.

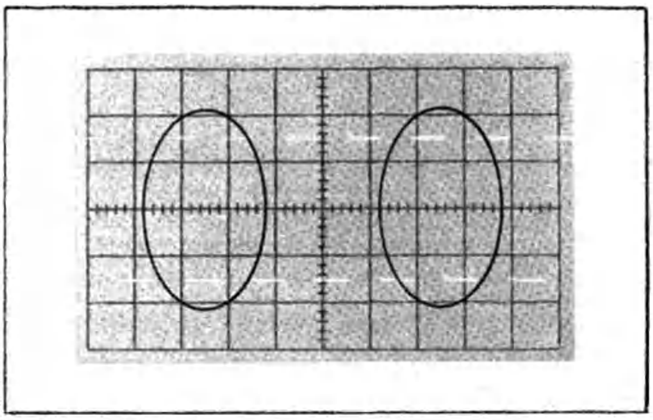


Fig. 2-8. Focus and Astigmatism adjustment waveform.

CHECK—The horizontal and vertical lines of the square wave should provide optimum sharpness at the same setting of the FOCUS control.

ADJUST—ASTIG and FOCUS controls until the corners of the square wave provide optimum sharpness. Concentrate on the areas contained in the ovals in Fig. 2-8 to obtain best overall focusing. Once FOCUS and ASTIG have been set, changes in intensity should only require readjustment of the focus control.

TRACE ROTATION

Set the VOLTS/DIV switch to 20 and position the trace to graticule center line.

CHECK—The trace should be parallel to the graticule center horizontal line.

ADJUST—TRACE ROTATION as necessary to set the trace parallel to the graticule's center horizontal line.

VERT ×10 BAL

CHECK—No vertical position shift of the trace occurs when the ×10 VERT GAIN control is switched in and out.

ADJUST—VERT ×10 BAL until minimum trace shift occurs when the ×10 VERT GAIN control is switched in and out. Return the ×10 VERT GAIN control to its in position.

VAR V/DIV BAL

CHECK—No trace shift occurs as the VARIABLE V/DIV BAL control is rotated from limit to limit.

ADJUST—VAR V/DIV BAL control until no trace shift occurs as the VARIABLE (VOLTS/DIV) control is rotated from limit to limit.

Return the VARIABLE (VOLTS/DIV) control to CAL.

Repeat the VERT ×10 BAL and the VAR V/DIV BAL adjustments until interaction is no longer noticeable.

VERT ×1 GAIN

Switch the TIME/DIV control to the 5 DIV CAL position. Using the Vertical POSITION control, center the square wave.

CHECK—The square-wave presentation has 5 divisions ±0.15 division vertical amplitude. The measurement should be made from trace center to trace center to avoid the effect of trace width.

ADJUST—VERT ×1 GAIN to provide a 5 division square-wave presentation.

VERT ×10 GAIN

Pull the ×10 VERT GAIN control out.

CHECK—The square-wave presentation has 5 divisions ±0.15 division vertical amplitude.

ADJUST—VERT ×10 GAIN to provide a 5 division square-wave presentation.

SIGNAL TRANSPORTING METHODS

VOLTAGE and waveform observations normally require that the oscilloscope be placed in parallel with the load across which the observation is being made. Numerous methods of connecting signal sources (signal pick-off points) to the oscilloscope are available. The method to be used is basically determined by signal amplitude and/or signal frequency or risetime compared to the combination of signal source impedance and oscilloscope input impedance.

Signal Amplitude

Signals in excess of the display range of the oscilloscope (120 V peak to peak calibrated, 300 V peak to peak uncalibrated) can be reduced to an observable value by means of an attenuator placed in the signal-to-oscilloscope path. The P6049 Probe provided with the Type 323 Oscilloscope makes

1/10th of the source voltage available to the oscilloscope vertical input connector.

The peak-to-peak measurement which can be made with the P6049 Probe-Type 323 Oscilloscope combination is 500 V DC + peak AC. Other Tektronix probes which allow measurement of voltages as high as 40 kV are available for use with the Type 323 Oscilloscope.

CAUTION

Never apply voltages in excess of 500 V to the VERT INPUT connector or to the P6049 Probe. Use a high-voltage probe to reduce higher voltages to an acceptable level.

Signal Source Resistance and Oscilloscope Input Resistance

The oscilloscope input resistance (1 MΩ) and the signal source resistance form a voltage divider. When the input resistance is high with respect to the source resistance, display amplitude for DC and low-frequency AC signals is a relatively accurate evaluation of the signal at the source. See Fig. 2-9(A).

As the size of the oscilloscope input resistance compared to the signal source resistance decreases, the display amplitude decreases. See Fig. 2-9(B). In addition to providing an incorrect display, such a situation loads a circuit to the point where an evaluation is being made of a false circuit performance.

The source-to-oscilloscope resistance ratio must therefore be kept high. The 1 MΩ oscilloscope resistance is sufficient for most applications. However, when the signal source impedance is as high as 0.11 MΩ, approximately 10% error is introduced. This error can be computed in DC and low-frequency applications, and the display evaluation can be corrected accordingly.

An easier method is to use a ×10 probe and a 10 times more sensitive volts/div setting. The P6049 Probe and Type 323 Oscilloscope combination have a resistance of approximately 10 MΩ. When used to evaluate the above-mentioned 0.11 MΩ circuit, the ratio of oscilloscope resistance to signal source resistance is increased to approximately 91:1 and display amplitude error is reduced to approximately 1%. Another important consideration is that the loading effect on the circuit becomes negligible and circuit performance is not affected.

Signal Frequency Versus Signal Source Capacitance and Oscilloscope Input Capacitance

The 47 pF oscilloscope input capacitance is of little concern when measuring DC or low-frequency signals. However, as frequency increases, the oscilloscope input capacitance in parallel with the signal source lowers the effective load impedance. Parallel capacitance inserted by signal transporting leads adds to the oscilloscope input capacitance and further lowers effective load impedance, decreasing AC and transient waveform display amplitudes. Signal transporting lead capacitance must therefore be kept as low as possible for AC or transient measurements.

When the signal source capacitance is high with respect to the oscilloscope input capacitance, AC display amplitudes are relatively accurate. The signal source capacitance to oscilloscope capacitance ratio can be improved by insertion of an attenuator probe in the signal path. Its effect upon AC and transients will be essentially the same as was its effect upon DC, both in increasing the effective range of the oscilloscope and in reducing loading effects.

Circuit current can be monitored with the Type 323 Oscilloscope and a current probe. One type of probe uses a device which can be clamped around or removed from the current-carrying wire in a few seconds. It is especially useful in working with current-driven transistor circuitry.

A summary of signal transporting information is provided in Table 2-1. Additional information concerning all Tektronix probes is contained in the Tektronix catalog.

PROBE ADJUSTMENT

Variations of total input capacitance and resistance occur with different combinations of oscilloscopes and probes. Therefore, many attenuator probes are equipped with adjustments to insure optimum performance. Explanations for performing Tektronix Probe adjustments are contained in the applicable probe manuals.

Because the P6049 Probe is a standard accessory for the Type 323 Oscilloscope, that particular adjustment procedure is repeated here.

P6049 Probe Adjustment Procedure

(a) Preset the Type 323 Oscilloscope controls as follows:

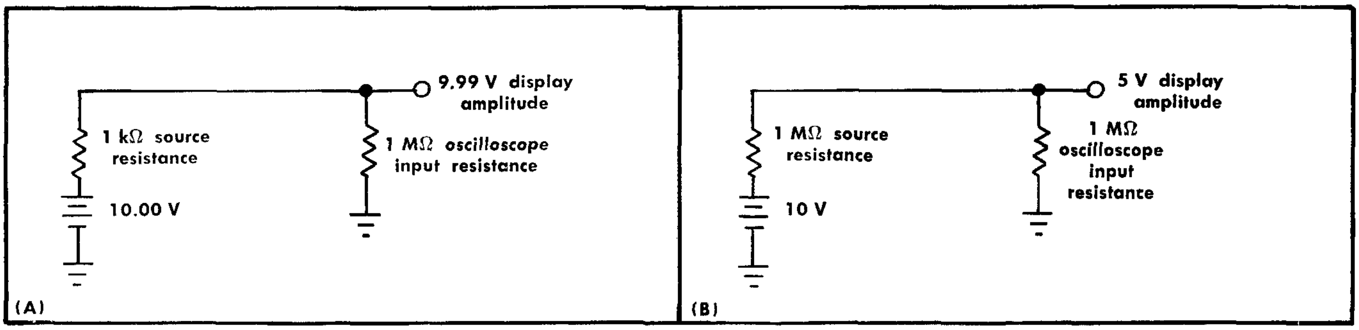


Fig. 2-9. Source resistance versus oscilloscope input resistance.

TABLE 2-1

Signal Transporting Methods, Passive

Method	Advantages	Limitations	Equipment Required[1]	Source Loading[1]	Precautions
Unshielded Test Leads	Availability	Limited frequency response; subject to stray pickup and oscillation	BNC-to-Binding Post Adapter; two test leads	Oscilloscope input impedance	Insert 47 Ω resistor in series with signal lead to suppress oscillations. Place leads strategically to reduce shunt capacitance and stray pickup
Unterminated coaxial cable or 1× probe	Convenience	Limited frequency response; high capacitance of cable	Coaxial cable with BNC connectors; or 1× probe	Oscilloscope input impedance plus cable capacitance	High capacitive loading
Coaxial cable terminated in characteristic impedance at oscilloscope	Full oscilloscope bandwidth. Provides uniform response while using long cables	Loading effect due to termination (typically 50 Ω); power limit of termination	Coaxial cable with BNC connectors and BNC termination (typically 50 Ω)	Termination value (Typically 50 Ω) in parallel with oscilloscope input impedance	Loading on test point; power limit of termination; Use DC-blocking capacitor between source and termination; reflections from oscilloscope input impedance
Terminated coaxial cable with coaxial attenuator between source and termination	Less reflection from oscilloscope input impedance; increased voltage range	Reduces oscilloscope sensitivity	Coaxial cable with BNC connectors; BNC coaxial attenuator; BNC termination	Termination value (typically 50 Ω) in parallel with oscilloscope input impedance	Loading on test point; power limit of attenuator and termination; use DC-blocking capacitor between source and termination
Tap into terminated coaxial system with a BNC T at oscilloscope input	Optimum signal transfer; no termination required at oscilloscope		BNC T; 2 signal cables with BNC connectors	Oscilloscope input impedance	Signal size may require use of attenuators
Attenuator probes	Reduces oscilloscope loading; increases voltage range; protects oscilloscope	Oscilloscope sensitivity reduced by attenuation factor	10×, 100× or 1000× probe	10× $\approx$ 10 MΩ and 10 pF 100× $\approx$ 10 MΩ and 2.5 pF 1000× $\approx$ 100 MΩ and 3 pF	
Current probe	Permits current evaluation without interrupting circuit		Current Probe; Amplifier (optional) increases range	R $<0.03\ \Omega$ L $<3\ \mu H$	

[1]See Tektronix catalog for specific equipment characteristics.

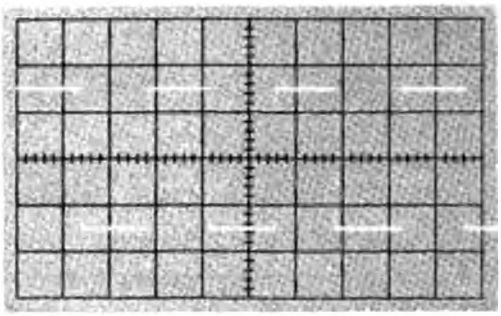
INPUT	DC
VOLTS/DIV	.02
VARIABLE (VOLTS/DIV)	CAL
TIME/DIV	.5 ms
×10 VERT GAIN	In
×10 HORIZ MAG	In
TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG-AC

(b) Connect the P6049 Probe BNC connector to the VERT INPUT connector.

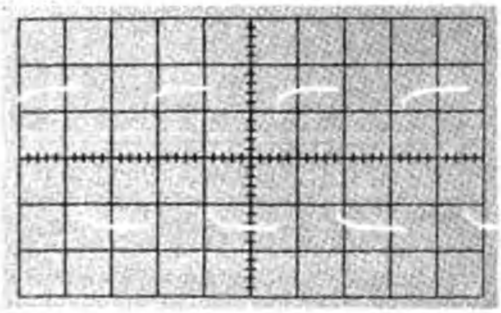
(c) Connect the P6049 Probe tip to the .5 V CAL OUT jack (left side of oscilloscope).

d) Check the waveform presentation against Fig. 2-10(A). Waveform presentations resulting from incorrect adjustments are shown in Fig. 2-10(B) and (C).

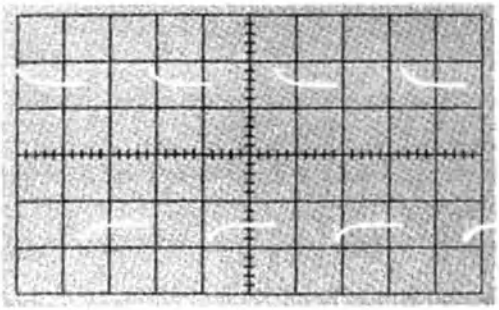
(e) The probe adjustment is contained in the compensation housing which connects to the Oscilloscope INPUT connector.



(A) Correct



(B) Incorrect



(C) Incorrect

Fig. 2-10. Probe compensation.

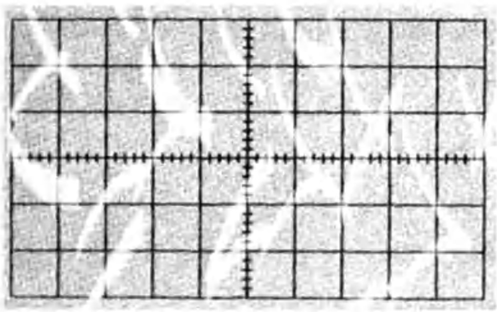
Using a screwdriver, adjust it as necessary to obtain optimum square leading corners on the square wave presentation. Rounding or overshoot should be minimized.

MISCELLANEOUS OPERATING HINTS

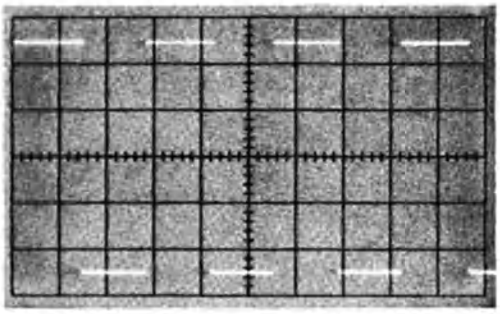
WARNING

Failure to complete the ground circuit of the Type 323 will cause the entire unit to be elevated to the voltage of the applied signal.

Reference or ground lead. Reliable signal observations cannot be made unless both the oscilloscope and the unit under test are connected together by a reference (ground) lead in addition to the signal lead. See Fig. 2-11. Most AC-operated equipment has a common ground supplied by the AC power source circuitry. This is true of the Type 323 Oscilloscope whenever the 3-wire AC line cord is connected to the oscilloscope and a grounded AC source. During internal battery or external DC operation, a reference (ground) lead must be externally connected between the oscilloscope and the equipment under test.



(A) Ground loop not completed.



(B) Ground loop completed.

Fig. 2-11. Ground loop effect.

Ringing. It is not uncommon to have ringing accompany a waveform presentation. It usually results from inductance associated with the reference or signal leads. If the AC supply common (ground) is used as the reference lead, the length of wire involved introduces considerable inductance. To reduce inductance and the resultant ringing, use the

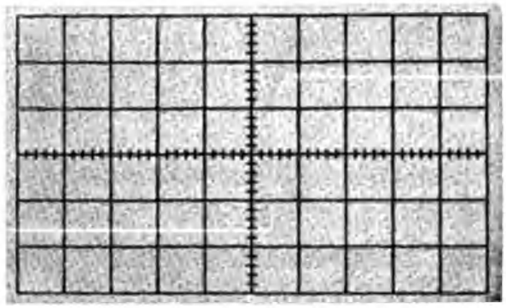
shortest possible probe ground lead and connect it to a ground point as near to the signal source as possible. See Fig. 2-12. If ringing persists, connect the Oscilloscope ground jack to the equipment under test, using the shortest possible lead. Then disconnect the external power leads and operate the Oscilloscope on its internal battery power.

Loading. Use a 10× probe whenever possible. It provides more accurate waveform observation by reducing the loading effect on the signal source. Deflection factors indicated by the VOLTS/DIV switch must be multiplied by 10 when a 10× probe is in use.

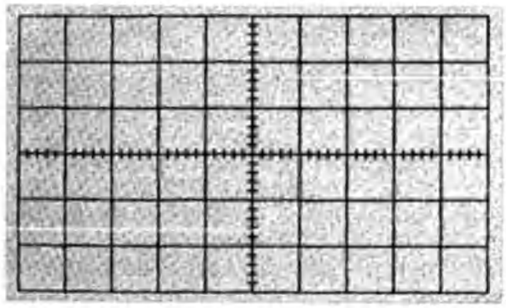
Phase and Polarity Relationships. When internal triggering is used, the signal slope displayed at the beginning of the sweep is dependent upon the trigger slope selected by the operator. If a comparison of phase or polarity is required, use external triggering and the same trigger source for the entire sequence of phase or polarity comparisons. The examples in Fig. 2-13(B) use + internal triggering and give the indication that the positive spike is coincident with the rising portion of the square wave. The examples given in Fig. 2-13(A) both use the same + external trigger source and show that the square wave actually goes negative at the time the positive spike occurs.

External triggering is extremely useful in measuring phase difference between signals. The circuit in Fig. 2-14(A) is used to demonstrate this feature.

Connect the reference waveform to the external triggering and the vertical input connectors. Select negative slope external triggering and adjust the triggering and horizontal

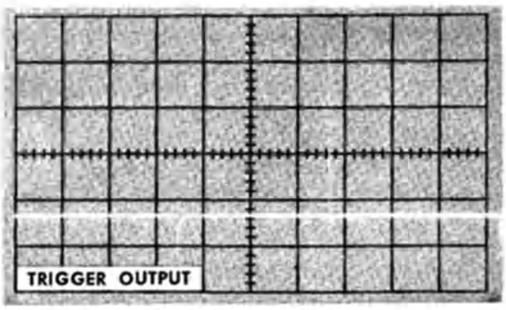


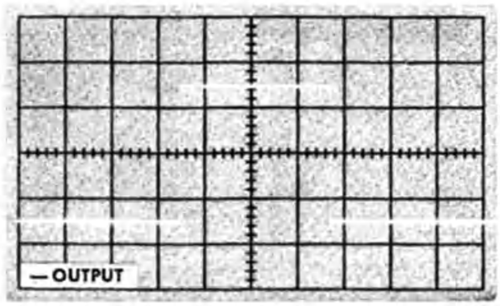
(A) Ground loop completed through power supply common ground.



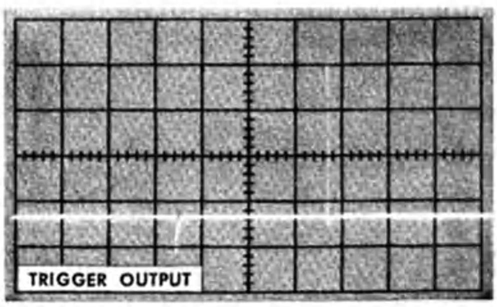
(B) Probe ground lead connected to equipment ground.

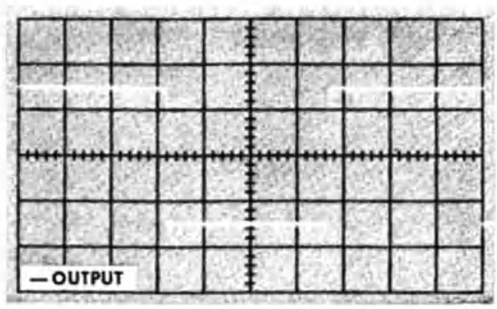
Fig. 2-12. Reducing ringing caused by ground loop.





(A) Synchronous signals observed with + external triggering show true time relationship.



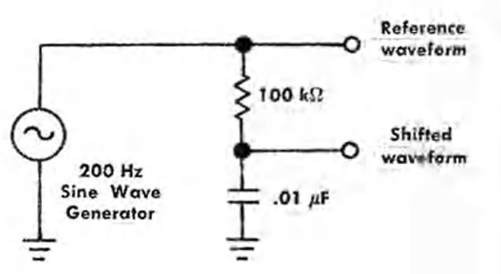


(B) Synchronous signals observed with + internal triggering show incorrect time relationship.

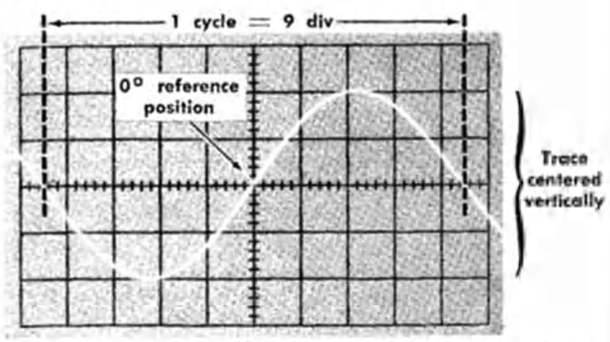
Fig. 2-13. Importance of external triggering for phase or polarity comparison. (Signals supplied by Tektronix Type 106 Square-Wave Generator.)

controls so that one cycle of the reference signal covers 9 divisions of horizontal trace, passing through 0° at the intersection of the graticule center lines as in Fig. 2-14(B). This causes each division of horizontal base line to display 40° of the waveform being applied.

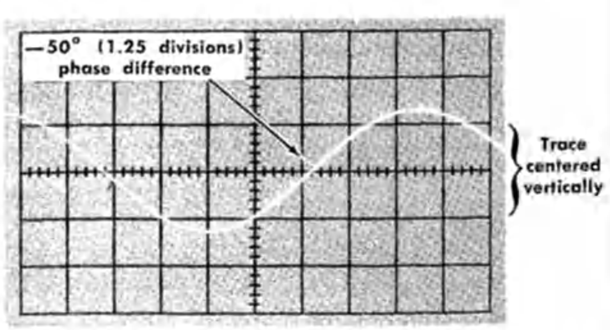
Disconnect the reference waveform from the vertical input. Connect the shifted waveform to the vertical input connector and measure the amount of separation between the graticule center line and the waveform 0° point as in Fig. 2-14(C). Convert the amount of separation to degrees, using the 40°/div value which was established previously. If the 0° point has moved to the left, the waveform leads the reference. If it has moved to the right, the waveform lags the reference.



(A) Circuit.



(B) Establishing a 9 div reference, using the generator waveform.



(C) Measuring phase relationship of waveform across the .01 μF capacitor.

Fig. 2-14. Measuring phase relationships.

Leading and Trailing Edges of Waveforms. The sweep in the Type 323 Oscilloscope is normally triggered by either the increasing (+) slope or the decreasing (—) slope of the applied signal. Thus, each sweep starts at a specific point on the waveform. If the beginning of the + or — slope is used to trigger the sweep, the slight delay before the sweep begins will prevent the triggering point from being seen. If the sweep rate selected is slow enough, the next pulse or cycle will be displayed before the sweep ends. However, if the pulse frequency is quite low, the sweep will not "stretch out" the area of interest enough to get a good look at it. Three methods are suggested to improve viewing of the beginning of a + or — slope.

(a) If the viewed signal is dependent upon another signal which occurs earlier, use the earlier signal to externally trigger the sweep. Use the horizontal sweep rate, position and magnifier controls as necessary to view the slope.

(b) Use the opposite slope to trigger the sweep; select the sweep rate which displays the point to be observed as near to the right of the sweep as possible (use the Horizontal VARIABLE control if calibrated measurement is not required); using the Horizontal POSITION control, set the point of interest to the center of the graticule; expand the sweep, using the ×10 HORIZ MAG control.

(c) Select a sweep rate which causes the trigger point to be repeated once near the right side of the sweep; using the horizontal position controls, set the repeated trigger point to the center of the graticule. Using the horizontal magnifier, expand the sweep.

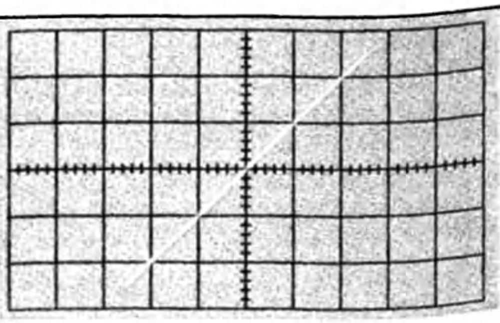
Amplitude Measurements. The Type 323 Oscilloscope can measure AC and DC signal amplitudes simultaneously or separately. However, best results will generally be obtained if they are measured separately, allowing selection of the best deflection factor for the component being measured. Example: Measuring the AC and DC components of a 0.02 V ripple riding on a 75-V power supply output. Establish a DC reference. Using DC coupling and a deflection factor of 20 V/division, the DC component causes 3.75 divisions of trace displacement, but the 0.02 V ripple component amounts to 1/1000 of a division and is not discernible. AC coupling and a deflection factor of 0.01 V/division displays two divisions of AC ripple without interference from the DC component.

Time Measurements. Although relatively accurate measurements are provided across the entire 10 horizontal divisions of the CRT, critical waveform time measurments should be made in the center 8 divisions.

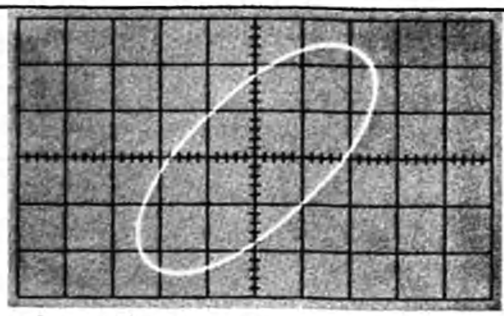
Frequency Measurements. To determine the frequency of a recurring event, find the reciprocal of the time (in seconds) it takes to complete one event. Example: With a sweep rate of 10 ms/div, a sine wave completes one cycle in 2.5 divisions (25 ms) of travel across the face of the CRT. $1/(25 \times 10^{-3})$ results in a frequency of 40 cycles per second, normally expressed as 40 Hertz (abbreviated Hz).

Arbitrary Units of Measure. The variable controls allow selection of arbitrary sweep rates and deflection factors. Examples follow:

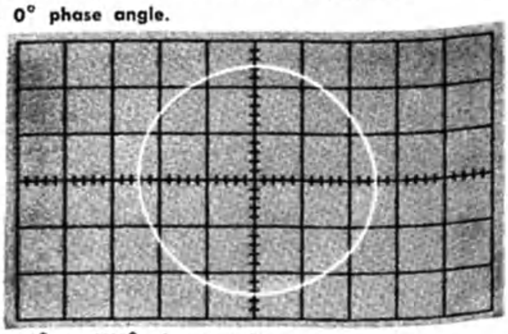
TIME/DIV: Use the 5 DIV CAL SIGNAL to establish a 0.4 ms/div sweep rate.



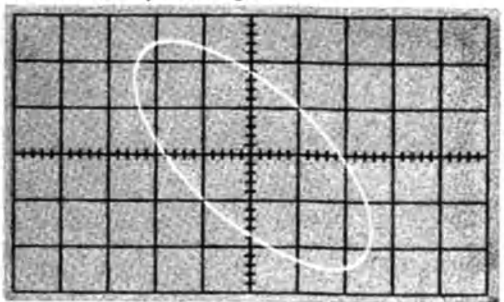
(A) 0° phase angle.



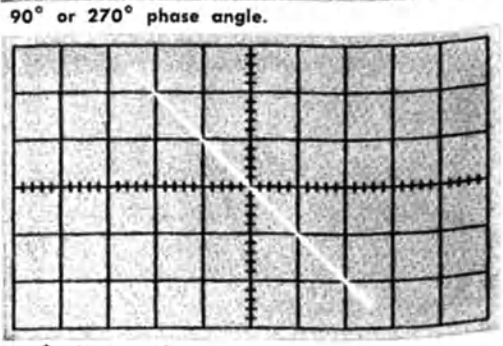
(B) 45° or 315° phase angle.



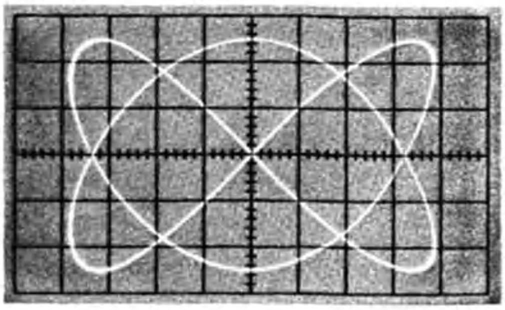
(C) 90° or 270° phase angle.



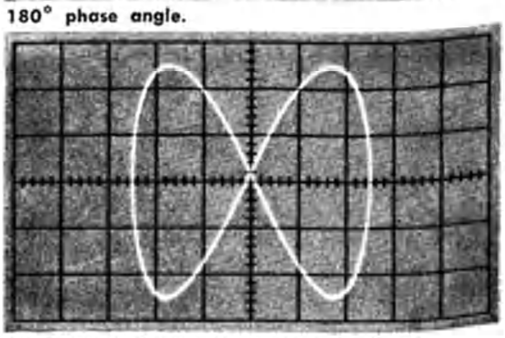
(D) 135° or 225° phase angle.



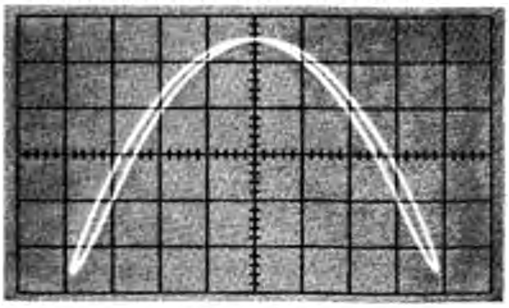
(E) 180° phase angle.



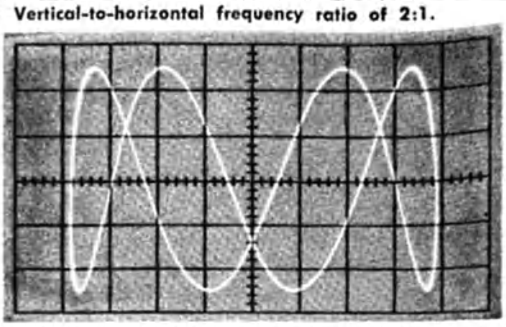
(F) Vertical-to-horizontal frequency ratio of 3:2.



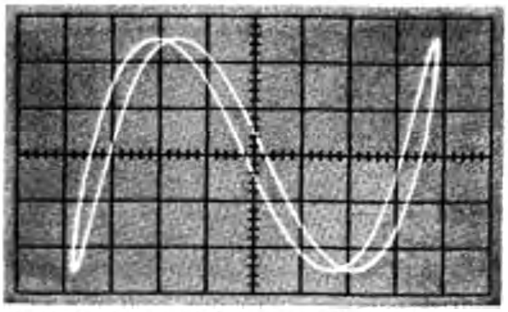
(G) Vertical-to-horizontal frequency ratio of 2:1.



(H) Vertical-to-horizontal frequency ratio of 2:1.



(I) Vertical-to-horizontal frequency ratio of 4:1.



(J) Vertical-to-horizontal frequency ratio of 3:1.

Fig. 2-15. Lissajous figures: (A) through (E) X and Y inputs having same frequency but different phase angles; (F) through (J) X and Y inputs having different frequencies which have a common divisor. Vertical to horizontal ratio is determined by the ratio I_h to I_v, where I_h is the number of times the trace intercepts a specific horizontal graticule line, and I_v is the number of times the trace intercepts a specific vertcial line.

1. Set the TIME/DIV control to .2 ms and determine the period time for 1 cycle.

2. Determine how many 0.4 ms divisions it takes to complete 1 cycle, by dividing the period time (from step 1) by 0.4.

3. Using the Horizontal VARIABLE control, set 1 cycle of calibrator waveform equal to the number of divisions determined in step 2.

4. A 0.4 ms/div sweep rate has been established. It may be noted that the ratio of actual-to-indicated sweep rate (0.4:0.2) exists in all positions of the TIME/DIV control.

VOLTS/DIV: Use the calibration signal to establish a 0.3 volts/div deflection factor.

1. Determine the ratio between the next lower calibrated deflection factor and the desired deflection factor (0.2/0.3). Multiply the ratio by 5.

2. Set the VOLTS/DIV switch to 5 DIV CAL.

3. Adjust the VOLTS/DIV VARIABLE control to obtain the fractional part of 5 divisions which was determined in step 1 (3⅓ divisions).

Lissajous Figures. An unlimited number of trace patterns (Lissajous figures) can be obtained by simultaneously applying signals of different frequencies or phase angles to the two input connectors. If the frequencies are different and do not have a common divisor, the pattern will change continuously. If the frequencies are the same, or have a common divisor, the pattern will be stationary, permitting phase, amplitude and frequency comparison. (The ease of comparison varies inversely with the ratio of frequency to common divisor.) One of the most practical uses of these patterns is in making extremely accurate adjustments of one frequency in respect to another.

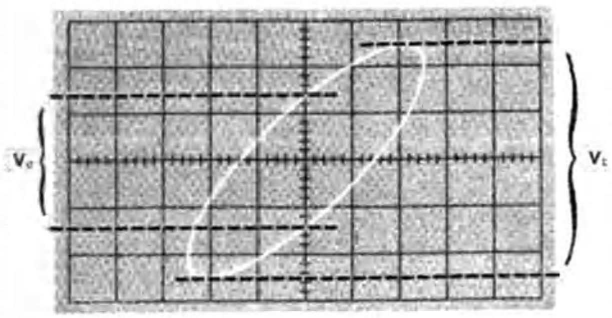
An analysis of these patterns is a science in itself, and beyond the scope of this manual. However, a few patterns and their interpretations are contained in Fig. 2-15 and 2-16.

The characteristics of the Oscilloscope's vertical and horizontal amplifier circuits must be considered in XY operation. Their bandwidth capabilities determine how much phase shift each one will introduce. For example, the horizontal circuit will introduce less than 5° phase shift at 10 kHz (its high-frequency half-power point).

The amount of difference in phase shift between the vertical and horizontal circuits will increase as frequency increases. This amount can be determined at any specific frequency. Couple the same signal into both the vertical and the horizontal input connectors and calculate the difference in phase which appears in the presentation, using the method which is explained in Fig. 2-16.

GLOSSARY OF TERMS

The terms and definitions contained herein are limited to information required to understand the material in this manual. If a term is synonymous with a preferred term, its definition is restricted to the name of the preferred term.



1. Center the display horizontally.
2. Measure total vertical amplitude (V_t).
3. Measure amount of center vertical line which is enclosed by ellipse (V_c).
4. Divide V_c by V_t to obtain sine of phase angle.
5. Determine phase angle from table of trigonometric values.
6. Angle is $>$ 270° and $<$ 090° if ellipse rises from left to right.
7. Angle is $>$ 090° and $<$ 270° if ellipse falls from left to right.

Fig. 2-16. Determining phase angle.

—3 dB Point—Half-Power Point

AC Coupling—The condition existing when a capacitor is inserted between the signal pickoff point and the circuit to which the signal is applied.

Accelerating Voltage—A voltage applied to components within a cathode-ray tube to accelerate beam electrons during their passage from cathode to phosphor screen.

Astigmatism—Any deviation from a circular appearance of the electron beam spot. Also the control which corrects for the deviation.

Attenuator—Normally, any device used to intentionally decrease the amplitude of a signal prior to its application to the oscilloscope's amplifier circuitry. Any device which decreases a signal's amplitude.

Automatic Triggering—Applies to the trigger circuit. A triggering mode in which triggers to the Type 323 sweep circuit will initiate triggered sweeps in response to a broad range of internal or external signals without adjustment of the triggering level control. It will also provide a free-running sweep for reference in the absence of triggers.

Balanced Circuit—Two symmetrical (electrically identical) branches or nodes of a circuit which carry equal but opposite polarity signals. Also called Push-Pull circuit.

Bandwidth—The frequency range through which a circuit will provide an output which is at least 0.707 times the voltage output provided at a reference frequency within said range. The limits are referred to as "Half Power" or "—3 dB Points". The lower frequency limit is understood to be DC if only one value is given.

Beam—The electron beam emitted by the cathode of a CRT. Its impinging on the phosphor creates the light on the face of the cathode-ray tube.

Bezel—The flange or cover which holds the external graticule, light filter, viewing hood, etc. in front of the cathode-ray tube face.

Blanked—Condition under which the electron beam is prevented from striking the cathode-ray tube face.

Blanking—The process of creating the blanked condition.

Blooming—An increase in display size accompanying an increase in CRT INTENSITY setting.

Calibration—Process whereby an instrument is adjusted to perform within specified limits.

Characteristic Impedance—An ohmic value which expresses an electrical quality of a transmission line or cable. It is the impedance the line would present if it were of infinite length.

Circuit Board—Any of various boards on which are mounted circuit components and inter-connections. The circuit board is usually fastened to a chassis with screws or clips.

Compression—An increase in the deflection factor, usually as the limits of the quality area are exceeded.

DC Balance—The condition existing in the Type 323 Oscilloscope when, with the vertical input grounded, no trace shift occurs as a result of any change in vertical deflection factor.

DC Coupling—The condition existing when no capacitor interrupts the path between the signal take-off point and the oscilloscope circuit to which the signal is applied.

DC Reference Position—The position on the oscilloscope graticule which is occupied by the trace when the input is grounded. Normally refers to the vertical circuit, but also pertains to the horizontal circuit during EXT HORIZ operation.

Decoupling—The process of removing AC signals or transients from the power supply voltages applied to a circuit. Usually refers to shunting AC and transient signals to ground by connecting a capacitor from the decoupling point to AC ground, and an impedance between the power supply and the decoupled point.

Deflection Blanking—Blanking by means of a deflection structure in the cathode-ray tube electron gun which traps the electron beam inside the gun to extinguish the spot, permitting blanking during retrace and between sweeps, regardless of intensity setting.

Deflection Factor—The ratio of the input signal amplitude to the resultant displacement of the indicating spot (volts/div).

Deflection Plates—Metal plates contained within a cathode-ray tube. Application of voltage to these plates creates an electro-static field which controls horizontal, vertical or blanking deflection of the electron beam.

Deflection Polarity—The relation between signal polarity and spot displacement direction. The Type 323 Oscilloscope has a positive deflection polarity, indicating upward and right deflection in response to + vertical and horizontal input signals, respectively.

Deflection Sensitivity—The div/volt ratio which describes the amount of deflection resulting from a unit of applied signal.

Differential Amplifier—An amplifier whose output signal is proportional to the algebraic difference between 2 input signals.

Differential Signal—The instantaneous algebraic difference between two signals.

Display—The visual presentation created by the electron beam on the face of a cathode-ray tube.

External Horizontal Signal—Any signal applied to the Type 323 Oscilloscope TRIG OR HORIZ INPUT connector for purposes of EXT HORIZ oscilloscope operation.

External Trigger—Any signal applied to the Type 323 Oscilloscope TRIG OR HORIZ INPUT connector for purposes of EXT TRIG oscilloscope operation. Also the trigger generated in response to this signal.

External Triggering—Introducing the triggering signal directly into the trigger circuit from an external source.

Field Effect Transistor (FET)—A semi-conductor device whose operation is analogous to a triode vacuum tube.

Free-Running Sweep—Continuously succesive sweeps occurring independent of triggers or input signals.

Geometry—The degree to which a rectilinear display on a CRT screen is accurately reproduced. Also the name of the control which adjusts this quality.

Graticule—A scale associated with the cathode-ray tube face.

Half-Power Point—The frequency at which the oscilloscope response limits the display amplitude to 70.7% of the actual voltage of the applied signal.

Holdoff—Sweep Holdoff.

Horizontal Amplifier—An amplifier for signals intended to produce horizontal deflection.

Horizontal Deflection—Horizontal movement of the cathode-ray tube electron beam away from its quiescent or no signal position.

Horizontal Displacement—The amount of horizontal space between electron beam quiescent position and instantaneous position.

Horizontal Gain—The voltage ratio of output to input signals associated with the Horizontal Amplifier.

Horizontal Sweep—The movement of the electron beam from left to right across the cathode-ray tube face in response to a changing horizontal amplifier voltage.

Input Coupling—Associated with the method of connecting a signal into a device or circuit. Usually refers to AC or DC coupling and signal attenuation.

Input Impedance—The combination of R, C and L which a

signal must supply with energy when the signal is applied to the input of a circuit.

Input RC Characteristics—The value of capacitance and DC resistance present at the input of the oscilloscope. Also referred to as input impedance.

Internal Triggering—Using a sample of the signal present in the vertical amplifier as a triggering signal source.

Jitter—An aberration of a repetitive display indicating instability of the signal or of the oscilloscope. May be random or periodic, and is usually associated with the time axis.

Lissajous Figure—A special case of an X-Y display, produced by simultaneous application of sine waves to the vertical and horizontal deflection plates. Useful for determining phase and frequency relationships.

Load—The impedance offered by a circuit or device. The lower the impedance, the greater the loading effect.

Loading—Requiring a circuit to supply energy to another circuit. The term is often associated with the effect caused by attaching test equipment to a circuit.

Magnified Sweep—Enlarged portion of a sweep (usually horizontal). In the Type 323 Oscilloscope, the sweep can be magnified so that 1 division of display is viewed over 10 divisions through use of the ×10 HORIZ MAG control.

Noise—Any extraneous electrical disturbance tending to interfere with the normal display.

Open Circuit—A discontinuous circuit.

Overshoot—In the display of a step function (usually of time), that portion of the waveform which, immediately following the step, exceeds its nominal or final amplitude.

Period—The time elapsing between occurrence of identical points in an AC or recurring transient event. It usually refers to repetitive waveforms and is the reciprocal of their frequency.

Phase Shift—The change in the phase angle (of a sinusoidal waveform) which is introduced when the waveform passes through a network.

Phosphor—The substance coating the inner face of a cathode-ray tube. It emits light when bombarded by electrons.

Plate—In a cathode-ray tube, any one of the deflection plates.

Preventive Maintenance—Cleaning, inspecting and lubricating equipment to insure continued reliable operation.

Probe—A pointed metal tip within an insulating handle. Used for temporarily connecting to a signal source. It can include attenuation capability. Generally includes the associated cable and connector.

Probe Tip—That part of a probe which makes contact with the signal pickoff point.

Pulse Width—The time between specified equal amplitude points on both slopes of an electrical pulse. Usually measured at the 50% amplitude points.

Push-Pull—Currents or voltages which are equal in amplitude but opposite polarity. Also defines a circuit which has that type of response.

Reflection—A signal caused by reflected signal energy. Usually thought of as energy returned by a transmission line which is not terminated in its characteristic impedance, or which has impedance discontinuities within it.

Response Characteristics—A quantitive description of the input-output characteristics of a device or circuit. Usually amplitude versus frequency response.

Retrace—Return of the spot to the left of the cathode-ray tube face upon completion of a horizontal sweep. Also that portion of the sweep waveform which causes the spot to return.

Retrace Blanking—The process of creating a CRT blanked condition during Retrace.

Return Trace—A path created by the spot during retrace. Should not be seen during normal sweep operation.

Ringing—A damped oscillatory transient occurring in a system as a result of a sudden change of input.

Ripple—AC superimposed on a DC level. Commonly associated with filtered DC power supplies.

Risetime—The interval between the instants at which the instantaneous amplitude first reaches specified lower and upper limits. In the display of a step function of time, these limits are 10% and 90% of the nominal or final amplitude of the step.

Rounding—In the display of a step function (usually of time), the loss of the corner following the step.

Sawtooth Waveform—A waveform containing a linear sloped rise and return to its initial value, the two portions usually of unequal duration. Commonly describes the waveform created by the oscilloscope horizontal sweep generator.

Semi-conductor Device—Any one of several devices made of semi-conductor material; usually diodes or transistors.

Sensitivity—See deflection sensitivity.

Short Circuit—A low impedance connection across circuit branches or power sources.

Signal Pickoff Point—A point at which a circuit is tapped into to provide a signal for any of various purposes, such as oscilloscope display.

Signal Source—The point of origin of a signal. Also used to describe Signal Pickoff Point.

Slope—In oscilloscope waveform presentations, the term describes the direction and ratio of change of vertical deflection related to change of horizontal deflection ($\Delta E/\Delta t$).

Source—The point of derivation of power or of a specific type of power (line, +300 V, −150 V, battery). Also the element in a Field Effect Transistor which operationally corresponds with the cathode of a triode vacuum tube.

Sweep—An independent variable of a display; unless otherwise specified, this variable is a linear function of time, but

may be any quantity that varies in a definable manner.

Sweep Generator—A unit that generates a signal used as an independent variable; the signal is usually a ramp, changing amplitude at a constant rate.

Sweep Holdoff—An interval immediately following a horizontal sweep, during which time the sweep is prevented from recurring while the circuits stabilize to their quiescent condition.

Sweep Linearity—Maximum displacement error of the independent variable between specified points on the display area.

Sweep Rate—The time required per division of trace movement (TIME/DIV).

Termination—The load present at the output of a circuit, device, or transmission line. Commonly identifies a device which terminates a transmission line with a specific impedance.

Tilt—Deviation of the upper and/or lower flat surfaces of a square wave or pulse from the horizontal.

TIME/DIV—The time required for the spot created by the electron beam to move 1 division. Commonly used in reference to horizontal sweep.

Time Base—The sweep generator in an oscilloscope.

Trace—The cathode-ray tube display produced by a moving spot.

Trace Width—The distance between two points on opposite sides of a trace at which the luminance is 50% of maximum.

Transient Response—The name of a number of characteristic time-domain reactions to abruptly-applied inputs.

Transient—A damped oscillation or pulse occurring in a circuit in response to a change in input.

Transition—A voltage shift; commonly refers to the step function of a square wave.

Trigger—A pulse used to initiate some function. In oscilloscopes, commonly refers to the signal which initiates the horizontal sweep.

Triggered Sweep—A sweep that can be initiated only in response to a trigger, as opposed to a free-running sweep.

Triggering Level—The instantaneous value of voltage of an input signal required to generate a trigger.

Triggering Signal—The signal from which a trigger is derived.

Triggering Slope—The direction of change (+ or —) of triggering signal voltage from which a trigger is to be derived.

Unblanked—The condition existing when the electron beam is permitted to strike the face of the cathode-ray tube.

Vertical Amplifier—An amplifier for signals intended to produce vertical deflection.

Vertical Deflection—Vertical movement of the electron beam.

Vertical Displacement—The amount of space between the vertical reference and actual trace positions.

Vertical Gain—The ratio of the amplitude of the output signal from the vertical amplifier to the amplitude of the vertical input signal.

Vertical Input Signal—The signal applied to the oscilloscope vertical input connector.

VOLTS/DIV—The ratio expressing the deflection factor of the oscilloscope. In front panel control nomenclature, it is the number of volts required to cause one division of vertical deflection.

X-Y Display—A rectilinear coordinate plot of two variables.

Z Axis—The third dimension of a display. Commonly implemented in oscilloscopes as beam intensity (display brightness) variation.

SECTION 3
CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

Block diagram and detailed descriptions of the Type 323 Oscilloscope circuitry are contained in this section. The block diagrams and schematics contained in the rear of this manual are used in conjunction with the descriptions. Numbers which are contained in diamond-shaped outlines appear in conjunction with the schematic names. These numbers are used extensively on the schematics for cross-referencing and are therefore contained in a diamond-shaped outline for quick recognition.

Simplified drawings are provided where necessary for effective circuit explanations. No attempt is made to explain basic operations of components except for those that are not considered generally known. Additional information regarding components is included in the Maintenance section of this manual.

BLOCK DIAGRAM DESCRIPTION

Refer to the block diagram contained in the Diagrams section. Operation with an internal sweep will be discussed first.

Internal battery, external DC, or AC powered operation can be selected at the Power Pack. During AC operation, the AC power input is full-wave rectified and applied to battery charger circuits which supply power to the external batteries and the oscilloscope circuits. During EXT DC operation the battery and battery charging circuit are bypassed and the applied voltage goes directly to the POWER switch.

In all modes of operation, a DC voltage is received by the Power Regulator, which employs a blocking oscillator and flyback-type transformer to develop the voltages which are used throughout the Oscilloscope. This includes CRT filament supply and high voltage.

When internal sweep operation is selected, the Trigger Generator develops triggers in response to any of three sources as selected by the operator: trigger multivibrator, vertical signal, or externally applied triggering signal. When the vertical signal or the EXT TRIG input is selected, the Comparator Amplifier causes the Trigger Multivibrator to generate a trigger each time the input signal passes through a specific voltage as determined by the Compartor Amplifier. When AUTO triggering is selected, the Trigger Multivibrator free-runs, providing a continuous succession of triggers. Whenver either a vertical signal or external triggering signal is present and has a higher frequency than the multivibrator's free-running rate, the multivibrator no longer free-runs but becomes slaved to the triggering signal.

The Trigger Multivibrator output enables a Sweep Gate circuit. This causes the Sweep Generator circuit to develop a linear sawtooth voltage, which drives the Horizontal Amplifier. The Horizontal Amplifier increases the amplitude of the sawtooth voltage as necessary to provide slightly more than ten division of horizontal deflection when the voltage reaches its peak.

When the sawtooth voltage out of the Sweep Generator rises sufficiently positive to provide full trace deflection, it disables the Sweep Gate and the sweep voltage returns to its reference value. The Holdoff Circuit prevents triggers from reaching the Sweep Gate during sweep time, and continues to block them until enough time has elapsed after sweep time for the circuits to return to their quiescent values. This ensures that each sweep will start from the same point at the left edge of the graticule.

Deflection blanking is used in the CRT to prevent the electron beam from striking the CRT face during retrace and holdoff time. The Sweep Gate output causes the Unblanking Amplifier to apply +100 V to an unblanking deflection plate during sweep time. This cancels the effect of the +100 V which continuously exists on an opposing deflection blanking plate, permitting the horizontal (and vertical) deflection plates to control beam position on the face of the CRT. The CRT beam can be blanked at any time by application of an external blanking signal of at least +5 V to EXT BLANK jack J350.

When a signal is applied to the VERT INPUT, it passes through an attenuator which is controlled by the VOLTS/DIV switch. The signal (or a portion of it as determined by the switch setting) is applied to the Vertical Preamp where it is amplified and converted to a push-pull signal. It is then amplified by the Vertical Output Amplifier which applies the signal to the CRT vertical deflection plates. The vertical signal applied to the upper deflection plate is also applied to the Trigger Generator circuit. This slaves the trigger and sweep generator to the input signal frequency, thereby permitting a stable display.

Alternate Modes of Operation

5 DIV CAL. The gain and the overall operation of the oscilloscope can be checked by switching the VOLTS/DIV switch to a 5 DIV CAL position. At that time a square wave is accepted from an internal Calibrator. The appearance of a 5 division square wave on the CRT is indicative of proper operation. Its amplitude is sufficiently accurate to permit gain calibration. A 0.5-V square wave signal from the Calibrator is always available at a CAL OUT jack for purposes such as calibrating an attenuator probe.

EXT HORIZ. The horizontal beam deflection can be controlled by an externally applied signal when the TIME/DIV switch is placed in the EXT HORIZ position and the Trig/Horiz Coupling switch is in an EXT TRIG OR HORIZ posi-

tion. At that time the Sweep Generator is disabled. The CRT becomes unblanked and the electron beam moves to center screen. Signals applied to the EXT TRIG OR HORIZ INPUT jack pass through the Trigger Input circuit to the Horizontal Amplifier, where they are amplified, converted to push-pull, and applied to the CRT horizontal deflection plates. Vertical deflection operation remains the same as previously described.

VERTICAL PREAMPLIFIER ⟨1⟩

Block Diagram Description

The principal sections and controls are shown on the block diagram which is contained on the Vertical Preamplifier schematic diagram page. Signals applied to the VERT INPUT connector can be AC or DC coupled into the attenuator section by the INPUT coupling switch. The position of the VOLTS/DIV switch determines the amount of attenuation the signal receives to provide the deflection factor indicated by the switch. One position of the switch allows selection of a square wave signal from a built-in calibrator unit to allow checking and calibrating of the oscilloscope circuitry. Two different calibrator amplitudes are available. The proper amplitude is automatically selected to present a 5 division calibration display in both positions of the ×10 VERT GAIN switch.

The input signal is applied to one half of a dual field effect transistor (FET) in the Source Follower circuit. The FET provides an extremely high input impedance, and nearly unity gain output. The second half of the FET provides an offset signal which cancels any thermal or power supply change effects upon the input FET.

The signal from the Source Follower is applied to the Paraphase Amplifier circuit where equal but opposite polarity signals are developed to provide a differential signal. The signal developed in the upper half of the amplifier eventually drives the cathode-ray tube upper deflection plate, while that out of the lower half of the amplifier drives the lower deflection plate. Therefore the terms "upper half" and "lower half" identify the two halves of the amplifier circuitry.

The normal single-ended input to push-pull output gain factor of the Paraphase Amplifier at Q61-Q71 is approximately 25, and increases to 250 when the ×10 VERT GAIN switch is closed. (The deflection factor indicated by the VOLTS/DIV switch must be divided by 10 to determine the actual deflection factor whenever ×10 VERT GAIN is in effect.)

The Clamper circuit clamps the Paraphase Amplifier output to a maximum of 0 and a minimum of —1.2 V. This limiting of the output aids in reducing the time required for the limiter to recover from overdriving signals.

The POSITION control injects a push-pull current through the Clamper and Limiter to the zero-impedance input nodes of the Buffer Amplifiers Q91 and Q99, decreasing the current in one side as the current increases in the other. The result is a change in the quiescent (reference) vertical position of the trace.

The Limiter (D86-D87, D88-D89) decouples the Buffer Amplifier from the Paraphase Amplifier during overdrive conditions. This prevents the Output Amplifier from being driven to a non-linear operating region during overdrive conditions. The Output Amplifier therefore requires a minimum of overdrive recovery time.

The Buffer Amplifier is an operational amplifier with unity gain. It provides the low impedance drive to the Vertical Output Amplifier which is necessary for good transient response.

Vertical Input Circuitry

Refer to the schematic. The Vertical Input Circuitry consists of the VERT INPUT connector (J20), the INPUT Coupling Switch (SW21), coupling capacitor C20, resistor R21, the input attenuators and the calibrator.

Input Coupling. With INPUT switch SW21 in AC position, C20 blocks the signal DC component while permitting the AC component to pass to the attenuator and preamplifier circuitry. In GND position, the switch connects the attenuator circuitry to ground to provide a DC reference for adjusting the trace vertical DC reference position. When switched to DC, the INPUT switch bypasses C20 and R21, allowing both the AC and DC signal components to be applied to the attenuator and preamplifier circuitry.

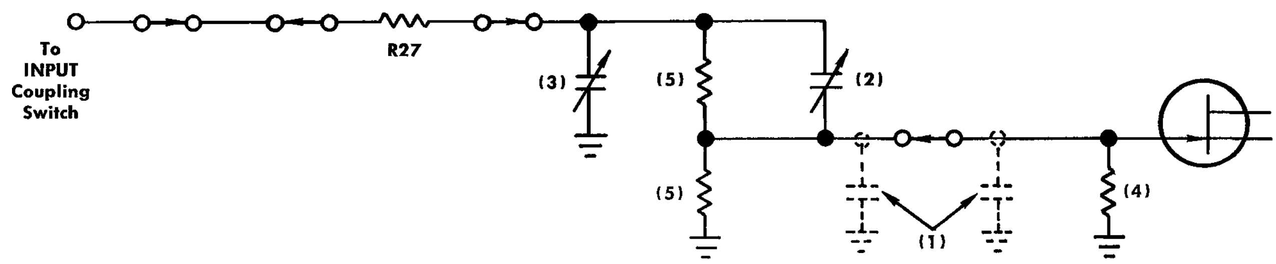
Vertical Input Attenuators. Eleven basic deflection factors (VOLTS/DIV) are made available through various combinations of five attenuator circuits and a "straight through" circuit. The combinations can be arrived at by connecting the attenuators as indicated at each switching postion of SW25 (VOLTS/DIV).

In the .01 (straight through) position, 1 MΩ and 47 pF oscilloscope input impedance is provided by the Preamplifier input cabling and stray capacitance. Attenuators are designed to maintain this same value of impedance at the VERT INPUT connector regardless of the attenuator in use. Since each attenuator has the same input impedance as the Preamplifier, attenuators can be connected in series and still maintain the 1 MΩ and 47 pF impedance at the VERT INPUT connector. The total attenuation affecting the signal is then equal to the product of the attenuation factors in use.

The attenuators are voltage dividers. DC voltage division is done solely by the resistors, while AC signals are attenuated by resistors, capacitors and stray capacitance at low frequencies. At high frequencies the attenuation becomes largely a function of the capacitors and stray capacitance.

Fig. 3-1 shows a simplifed input circuit configuration for .01, 0.2, or .05 VOLTS/DIV switch settings. Brief descriptions of component functions are included.

Calibrator. The simplified calibrator multivibrator circuit is shown in Fig. 3-2. Its explanation begins with the assumption that Q1 is conducting and Q9 is cut off. Under this condition Q1 is saturated and its emitter is at approximately



(1) Attenuator output capacitance and Preamplifier circuit input capacitance.

(2) In combination with (1), provides the AC voltage division indicated by the selected attenuation factor.

(3) In parallel with the (1) and (2) series combination, provides 47 pF input capacitance.

(4) 1 MΩ input resistance.

(5) In combination with (4), provides a 1 MΩ input resistance. Also provides voltage division as determined by the VOLTS/DIV switch position.

R27 limits current caused by over-driving signals in .01 mV position.

Fig. 3-1. Simplified input circuit configuration for .01, .02 or .05 VOLTS/DIV switch positions.

+4.4V. C5 is being charged through R9 by the 9.4 V difference existing between the —5 V power supply and the Q1 emitter voltage. Initially, the current through R9 is sufficient to keep the Q9 emitter more positive than —0.6 V, preventing Q9 from conducting. When C5 charges to approximately 5 volts, the current through R9 is decreased sufficiently to lower the Q9 emitter voltage to approximately —0.6 V and Q9 goes into saturation. The Q9 collector and the base of Q1 decrease to about —0.6 V, causing Q1 to cut off. C5 discharges through R4 until the Q1 emitter reaches about —1.2 V and Q1 again conducts. C5 stops discharging and Q9 cuts off. The voltage at the collector of Q9 goes positive, causing Q1 base and emitter voltage to follow. C5 again charges through R9, and the cycle repeats itself at an approximate 750 Hz rate.

Refer to the Vertical Preamplifier schematic. The multivibrator square-wave output is taken from the collector of Q9 and applied to the D11-D12 switching circuit. When Q9 is cut off, D11 is back biased by the positive potential at the Q9 collector. Current flows through R12, D12 and R15 to provide 0.5 V, .05 V and .005 V at the top of R17, R18 and R19 respectively. When Q9 conducts, D11 also goes into conduction and the voltage at the bottom of R12 drops below +0.6. D12 stops conducting and the output voltages drop to 0.

R3, R6, C3 and C6 are decoupling components. R13 and D13 counteract temperature effects on D12 to maintain an accurate calibration signal over the Oscilloscope's operating temperature range.

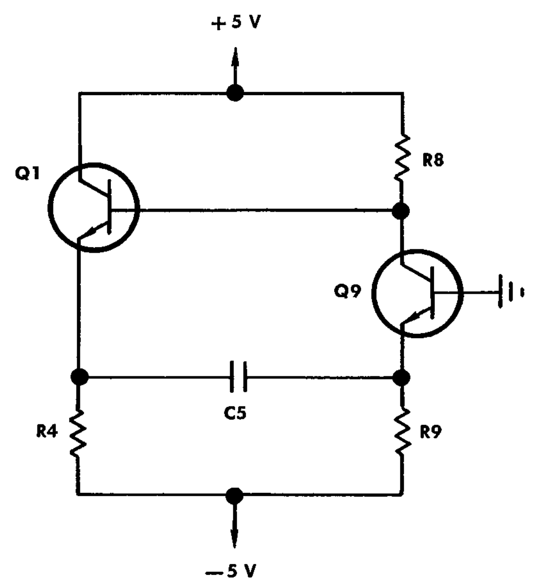


Fig. 3-2. Calibrator multivibrator, simplified.

Source Followers

Input signals are developed across R30 and applied through C31 and R31 to the gate of Field Effect Transistor (FET) Q33A. No signal current flows through the gate of Q33A, and therefore no signal loss occurs across R31. The operation of N-channel FETs such as Q33 is comparable to that of a triode vacuum tube, with the source, gate and drain comparing to the cathode, control grid and plate respectively. In typical cathode-follower fashion, most of the signal at the gate of Q33A is developed across R36 and applied to the base of Q41A. R34 and R39 permit adjusting for offset differences between Q33A and B, and between Q41A and B.

Q33A and Q33B are electrically and thermally paired, and therefore provide identical input conditions for both halves of the amplifier. This provides high common-mode rejection characteristics for the two halves which results

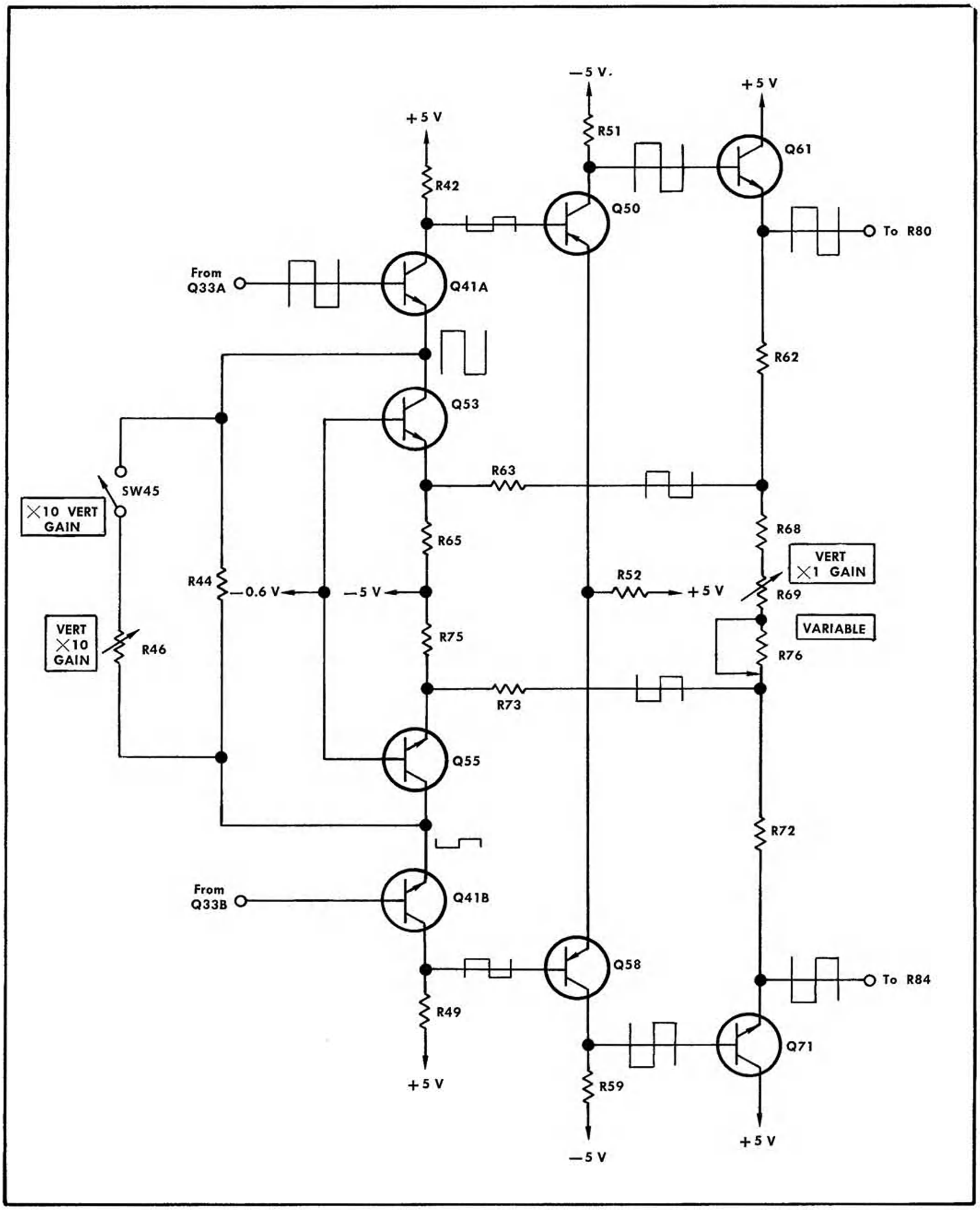


Fig. 3-3. Paraphase Amplifier, simplified.

in cancellation of effects from + and − 5 V power supply variations and FET thermal variations.

R33 and C33 are decoupling components. D30, D31, D32, and D33 provide protection to Q33A by limiting input signals to approximately ±1.2 V. R31 limits the overload current to a safe value during conduction of the diodes. C31 permits high frequency components of signals to bypass R31 to provide optimum transient response.

Paraphase Amplifier

Refer to the simplified schematic in Fig. 3-3 during the following explanation.

Under no-signal (quiescent) conditions, equivalent points on the two sides of the amplifier are at equal potentials. Therefore, no current is flowing through either R44 or R69. Standing current for both Q53 and Q61 flows through R65. The R65 current is kept relatively constant by the fixed potential at the R65-R75 junction with respect to that at the base (and therefore the emitter) of Q53. If the current through Q61 increases, the current through Q53 must decrease because of this R65 constant current feature. A similar explanation applies to Q71, Q55 and R75.

When a positive signal is applied to the base of Q41A, it is coupled into the emitter, where it unbalances the voltage across R44. Current flows through R44, increasing the Q41A current and thereby increasing the current drive to Q50. The low emitter impedance of Q50 as compared to its high collector load impedance causes an amplified positive voltage signal to appear at the base of Q61. This signal is coupled to the Q61 emitter where it demands an increase in current through R62 and R63. Since the R65 current is constant, the increase must be accompanied by an equal but opposite current change through Q53. In effect, the Q53 current is decreased by an amount which is almost equal to the current in R44, with the difference between the two giving sufficient error current drive to Q50 (via Q41A) to obtain proper circuit response.

The current change which flows through R44 in response to the positive input signal also flows through Q55. Since the R75 current is kept relatively constant in the same manner as the R65 current previously mentioned, the R44 current decreases the current through Q41B, decreasing the Q58 drive current. An amplified negative signal voltage is therefore developed at the base of Q71 and coupled to its emitter, where it decreases the current demanded through R72 and R73. This decrease is accompanied by an equivalent increase through Q55, supplying most of the current which was demanded through R44 by the original positive input signal.

It should be noted that the increase in Q61 current is accompanied by a positive signal at the R62-R68 junction, while the decrease of Q71 current causes a negative signal at the R72-R76 junction. This unbalance causes some of the Q61-Q71 signal current to flow through R69. If the resistance of R69 is increased, less signal current will flow through it. Consequently, less flows through R62 and R72, causing less signal voltage output to R80 and R84. R69 is adjusted to provide calibrated gain when the effective resistance of R76 is 0 and the ×10 VERT GAIN switch is open. Circuit gain decreases to 40% or less of the calibrated amount when R76 is fully inserted into the circuit.

Refer once more to the Q41 emitter circuit. If R46 is switched into the circuit, it effectively decreases the resistance between Q41A and Q41B. More current then flows between the emitters of Q41 for a given input. A larger output must be generated at the emitters of Q61 and Q71 to compensate for the increased current demand. Closing the ×10 VERT GAIN switch increases circuit gain by a factor of 10. R46 is adjusted to provide accurate gain while the ×10 VERT GAIN switch is closed.

VAR V/DIV BAL (R40), in the collector circuit of Q41, permits balancing of the two sides of the Q41 circuit. C50 and C58 improve transient response through regenerative high frequtncy feedback. Voltage dropping resistor R52 sets the current through Q50 and Q58.

The base-biasing network of Q53 and Q55 consists of thermal compensation components D54 and R54, voltage divider R55 and R56, and decoupler C56. Temperature variations cause slight differences in voltage to occur at the anode of D54, resulting in slight voltage changes at the bases of Q53 and Q55 to offset thermal effects on the transistors.

Total circuit current can be modified slightly by LIMIT CENTERING (R66). The current equally affects both sides of the amplifier and thus causes identical voltage changes at the emitters of Q61 and Q71. LIMIT CENTERING is adjusted to cause D86, D87, D88 and D89 to clip the signal when the trace reaches equal distances beyond the top and bottom of the CRT graticule area.

R61 and R71 pass the majority of the standing current for Q61 and Q71 operation. This is added to by slight amounts of current in the previously described feedback path and by current to the POSITION control and the Limiter circuit.

The POSITION control connects to a dual potentiometer. Movement of the control results in application of opposite voltage changes to R81 and R83. R81 and R83 are connected through the limiter circuits to the relatively low impedance nodes of operational amplifiers Q91 and Q99. Changing the POSITION control setting therefore injects positioning currents into these nodes in the same way as signal current is injected through R80 and R84. Any displacement of the trace in response to a signal will be in respect to the vertical DC reference which is established by the POSITION control.

Clamper and Limiter Circuits

Clamper. R85 and D85 form a divider which supplies approximately −0.6 V as a clamping reference. If D86 or D87 cuts off, one of the opposite-polarity diodes will conduct in each half of the amplifier, thus clamping the D86 anode to a −0.6 V ±0.6 V operating range. The Limiter circuit is therefore capable of fast recovery from overdriving signals.

Limiter. With the LIMIT CENTERING (R66) control properly set and the trace at graticule vertical center, −0.9 V exists at the D86-D87 and the D88-D89 junctions. This causes approximately 0.2 mA to flow through R87 and R89, dividing equally between the diodes. The anodes of D87 and D89 are set to approximately −0.6 V by the base-emitter junctions of Q91 and Q99.

The effect of signals on the Limiter in the upper half of the amplifier is explained in this paragraph. (The reaction of the lower half is identical, but is always of opposite polarity to that of the upper half.) A forward current signal through D86 subtracts from the current through D87 and the Q91 circuit. When all of the R87 current is demanded by D86, D87 cuts off. A negative signal at the anode of D86 causes an opposite reaction. In each case, when D86 or D87 cuts off, larger signal changes are prevented from reaching amplifier Q91. This prevents the Vertical Output Amplifier from being overdriven.

Buffer Amplifier

The Buffer Amplifier consists of two identical operational amplifiers with a gain of approximately one (from the emitters of Q61 and Q71 to the collectors of Q91 and Q99). These operational amplifiers provide low impedance drive to the Vertical Output Amplifier. The Q91 amplifier circuit is explained here.

A simplified circuit, with approximate values of voltage and current under quiescent conditions, is shown in Fig. 3-4. With a decrease in current through D87 and the Q91 base, the collector of Q91 goes negative. This increases the voltage across R95 and causes most of the D87 current change to be shunted through R95. The resultant negative output signal is taken from the collector and routed to the Vertical Output Amplifier.

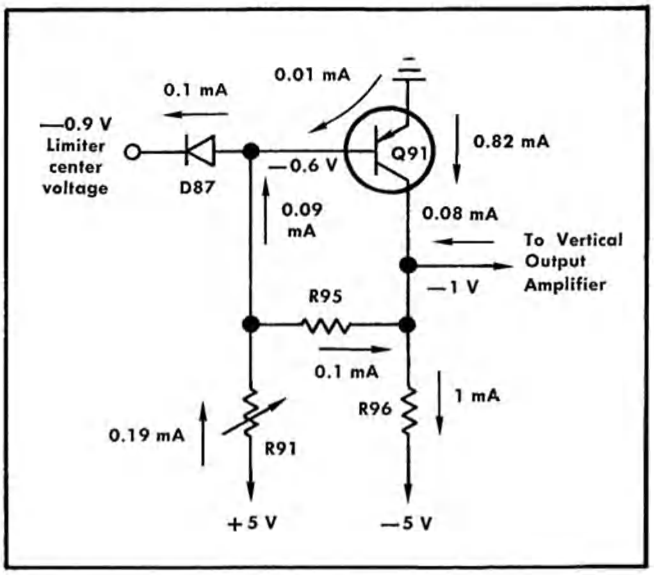


Fig. 3-4. Buffer Amplifier, simplified.

It is possible for the vertical amplifier to be balanced and the trace to be at graticule vertical center through a wide range of equal voltages at the upper and lower deflection plates. The DEFLECTION PLATE DC LEVEL adjustments (R91 and its counterpart in the lower half of the amplifier) permit individual adjustment and balancing of the deflection plate voltages, independent of the inputs from the limiter circuit. This enables the CRT vertical deflection plate voltages to be centered within their dynamic operating range.

VERTICAL OUTPUT AMPLIFIER ⟨2⟩

General

A basic knowledge of operational amplifier theory is helpful in understanding the Vertical Output Amplifier and other circuits in the Type 323 Oscilloscope. The following explanation is therefore provided. Refer to Fig. 3-5 and assume that:

Points B, C and D are initially at 0 V.

Any voltage at C will produce an amplified, inverted output at D.

Amplifier "A" has a gain of 1000 between points C and D, which is referred to as "open loop" gain.

When a +1 V signal is applied to B, point C attempts to go toward +1 V. When C arrives at +0.1 V, the gain of Amplifier "A" causes —100 V to appear at point D. Current through R_F (100.1 V ÷ 100.1 kΩ = 1 mA) becomes equal to current through R_I (0.9 V ÷ 900 Ω = 1 mA). Any further change occurring at C will cause a change at D, driving C back to 0.1 V as long at +1 V exists at point B.

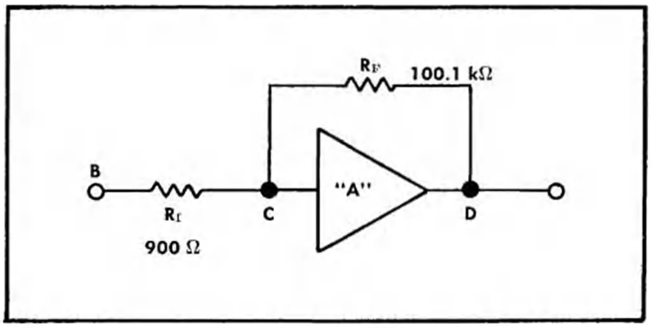


Fig. 3-5. Operational Amplifier, simplified.

The overall gain of the circuit (closed loop gain) therefore is equal to the 100 V output divided by the 1 V input, or 100, despite the fact that the gain of amplifier "A" is 1000.

The closed loop gain of operational amplifiers is approximately equal to the ratio between feedback resistor R_F and input resistor R_I. In the foregoing example the division results in 111. The closed loop gain of 100 is within 10% of 111. It may be noted that the accuracy of this approximation decreases as the value of the closed loop gain approaches the value of the open loop gain.

Block Diagram Description

Refer to the Vertical Output Amplifier block diagram. The Vertical Output Amplifier consists of a pair of multistage operational amplifiers quiescently supplying approximately 50 V DC to each of the vertical deflection plates of the cathode-ray tube. Signals at the VERT INPUT con-

nector cause equal and opposite deviations from this value at the two plates, resulting in approximately 1 division of deflection for each 18 volts of differential signal output. Overall gain of the circuit is approximately 90, determined principally by the quotient of R160 (R_F) divided by R101 (R_I). (Gain for one side is the same as push-pull gain.)

The top half of the amplifier is explained here. The input signal passes through R101 and a comparator stage. The output of the comparator goes through an emitter follower and then to the output amplifier, which supplies the signal to the upper deflection plate.

The two halves of the amplifier operate in push-pull. Current in one side decreases as it increases in the other side. During high frequency operation, rapid signal changes required at the CRT require that additional current be available in the output stage. The High Frequency Boost Circuit supplies this extra current.

Detailed Description

Quiescent Conditions. Refer to the Vertical Output Amplifier schematic diagram. When the trace is positioned at graticule center and no signal is applied, the voltage applied by Q91 and Q99 to the inputs of the amplifier causes the collectors of Q163 and Q173 to be at +50 V. Almost all of the feedback current through R160 and R170 flows through input resistors R101 and R108.

The voltage at Q103 base is equal to and controlled by the Q111 base voltage, which is established by the R114-R115 voltage divider.

With base conditions of the input transistors thus established, the current through R104 is divided between Q103 and Q111. The resultant drop across R111 establishes the base voltage of Q121, and thus its emitter voltage. The difference between the emitter voltage and the −5 V supply sets the current through R123, which is then divided between Q121 and Q133. The determining factor in the Q121-Q133 current division is the base voltage of Q133, which is established by a voltage divider in its base circuit, in conjunction with the amount of conduction of Q141. The total closed loop action sets the Q133 current so that the voltage drop across R131 causes Q160 to conduct enough to supply the necessary current through Q163 and R160 to establish the 50 V CRT deflection plate potential.

The emitter of Q121 also sets the base voltage of Q163. The resulting voltage at the emitter of Q163 (and the voltage at Q173 in the lower half) then determines the amount of current through R169, which establishes the standing current of the entire Q160, Q163, Q170, Q173 output stage. The anode voltage of D169 is determined by the Q163-Q173 emitter voltages and is slightly less than that required for D169 conduction.

Low Frequency Operation. When push-pull signals arrive at the inputs to R101 and R108, they cause equal and opposite reactions in the two halves of the amplifier. A negative signal voltage at R101 attempts to decrease the DC voltage at the base of Q103. Current decreases through Q103 and increases through Q111-R111. The negative-going voltage change at R111 decreases the current through Q121 and diverts it to R135, Q133, and the base-emitter junction of Q160. The resulting increased drive to Q160 causes its collector voltage to rise, raising the upper deflection plate voltage. The R160 feedback current changes in proportion to the deflection plate voltage change to null out the input error signal at the base of Q103.

High Frequency Operation. Large transient currents are necessary in the output circuit (Q160, Q163) to charge and discharge the deflection plate capacitance if the plates are to respond to high frequency or fast transient waveforms. Additional circuitry is put into operation to satisfy these demands. A finite time is required for the loop to respond to input signals. If the signal at the upper deflection plate tends to lag a single very fast negative-going input wavefront, less than the required amount of feedback is available through R160, and a larger than normal error signal develops at the base of Q103. The resulting increased current drive through R135 and Q133 causes Q160 to conduct the necessary transient current to charge the deflection plate capacity positive quickly enough to reproduce the input waveform faithfully. The error voltage at the base of Q163 is in the direction to reduce or turn off its current, further helping Q160 to charge the capacity.

When a single very fast positive-going input wavefront is applied, current drive to Q160 is decreased, and a positive-going error signal is applied to the base of Q163, increasing its collector current to enable the deflection plate to respond rapidly in a negative direction. C167 and C169 provide bypass paths to satisfy the increased current demands of Q163 during this error operation.

If these input wavefronts are repetitive rather than single events, the unidirectional transient current flow into C167 and C169 will cause them to charge positive, thereby cutting off Q163 and Q173 during the quiescent condition following the wavefronts. To counteract this, the increased signal amplitude occurring at the base of Q163 during high-frequency operation is coupled through C155 to the base of Q151. The emitter-base junction of Q151 operates as a peak detector during the positive signal peaks, placing a positive charge on C143. The resulting decreased current through Q141 raises its collector voltage, which is common to the base of Q133. The Q133 emitter follows, raising the voltage at the base of Q163. This raises the Q163 emitter voltage, which causes D169 to go into conduction, causing the DC current through Q160 and Q163 to increase for as long as the signal is present. This increased current discharges C167 and C169 between wavefronts.

It may also be noted that when the collector voltage of Q141 goes in a positive direction, feedback action through R160 and R170 (back to the input) causes the Q121 and Q127 base potentials to increase by the same amount. This allows the average DC CRT plate potential to remain at 50 volts.

It must be remembered that this amplifier is a push-pull device, with the two sides reacting in opposite directions from each other. Therefore, when the action described during a negative input signal is occurring at the upper half, the action described during a positive input signal is occurring at the lower half. The peak detection which occurs in both halves (through Q151 and Q153) has a common

effect, simultaneously changing the base voltages of Q133, Q137, Q163 and Q173.

Miscellaneous Circuit Components. C102, C160, C107 and C170 insure that the ratio of feedback impedance to input impedance remains constant regardless of frequency, to avoid high frequency gain changes which would otherwise be introduced by stray capacitance. C162, R162, C172 and R172 provide a shunt impedance across Q133 and Q137 to aid in the development of high frequency drive signals to Q160 and Q170.

TRIGGER GENERATOR 3

General

The function of the Trigger Generator is to develop triggers to initiate horizontal sweeps. In EXT HORIZ mode, part of the Trigger Generator circuit processes external horizontal signals for application to the Horizontal Amplifier.

Block Diagram Description

Refer to the block diagram contained on the Trigger Generator schematic diagram page. Signals from the Vertical Output Amplifier or the EXT TRIG OR HORIZ INPUT are applied to a protection circuit and then to an FET Source Follower circuit. Trigger signals pass through the TIME/DIV switch to a Comparator Amplifier. When the input signal reaches the voltage level determined by the (TRIGGER) Level control, the voltage out of the Comparator Amplifier causes the Trigger Multivibrator to generate a trigger. The TRIGGER control can be used to select the direction of voltage change (+ or — Slope) which actually causes triggers to occur.

When AUTO operation is selected by the TRIGGER control, the Trigger Multivibrator free-runs at one of 3 frequencies (approximately 30 Hz, 300 Hz, 3 kHz) as determined by the TIME/DIV control. Triggers occur more often at higher sweep rates to maintain a relatively constant trace brightness regardless of sweep rate. A triggering signal whose frequency is higher than that of the multivibrator will override the automatic operation and synchronize the multivibrator (and therefore the sweep) to the signal frequency.

In EXT HORIZ mode, external horizontal signals pass through the Source Follower circuit and are routed to the Horizontal Amplifier by contacts of the TIME/DIV switch.

Protection and Source Follower Circuits

Refer to the Trigger Generator schematic (and to the Timing Switch schematic as necessary). Circuit operation during non-automatic internal triggering will be discussed first. The output signal from the upper half of the Vertical Amplifier is coupled through the C201-R201 attenuator circuit to a contact of the Trig/Horiz Coupling switch. With the switch in either internal position, the signal is applied to C209. The AC component is developed across R210 and applied through R212-C212 to the junction of D213, D214 and Q215. Under normal conditions, only leakage current flows in the Q215 gate circuit, so no signal loss occurs across R212. D213, D214, C212 and R212 provide overload protection for Q215 during EXT TRIG OR HORIZ operation and have no effect upon the internal vertical signal applied to Q215. Source-follower action (comparable to cathode-follower action) provide the signal to a contact of the TIME/DIV switch. In all except EXT HORIZ position, the output of the source-follower is sent through or around C221 and C223 to the base of Q231. With the Trig/Horiz Coupling switch in INT TRIG AC LF REJ, signals below approximately 30 kHz are attenuated, to avoid interfering with higher frequency triggering operation. During INT TRIG AC operation, C223 is bypassed and triggers are generated in response to signal frequencies as low as 20 Hz.

External triggering can be selected by placing the Trig/Horiz Coupling switch to either the EXT TRIG OR HORIZ — AC or DC position. DC triggering is possible only when the switch is at DC and the TRIGGER control is not at AUTO. At that time, C209, C221 and C223 are bypassed to permit the EXT DC potential to reach Q231.

The 10× position of the (EXT TRIG OR HORIZ) ATTEN switch provides a frequency-compensated voltage divider which increases the EXT TRIG OR HORIZ INPUT operating range by a factor of 10, without appreciably changing circuit input impedance.

When the TIME/DIV switch is set at the EXT HORIZ position, the output of Source Follower Q215 is disconnected from the trigger generating circuitry and is routed through switch contacts to the Horizontal Amplifier. Horizontal deflection of the beam then occurs in response to external horizontal input signals (Trig/Horiz Coupling switch in either EXT TRIG OR HORIZ position) and the horizontal POSITION control. R218 permits setting of the voltage at the source of Q215 so that no beam position shift occurs when rotating the (EXT HORIZ) VAR control.

Comparator Amplifier

The Comparator Amplifier (Q231, Q239 and associated resistors) quiescently has the Q231 base referenced to ground through R230. The Q239 base is set to some voltage level determined by R246 (TRIGGER LEVEL), R242 and R244. If R246 is set to a point midway between the center tap and either side, 0 V will be applied and the two transistors will be conducting equal current. The collector voltages will be approximately equal under those circumstances. A signal input to the Comparator Amplifier will generate an in-phase signal at the Q239 collector and an inverted signal at the Q231 collector. Both outputs are made available to contacts of the (TRIGGER SLOPE) switch.

Triggering action occurs when the selected collector varies approximately —0.1 V from a balanced output condition. If the TRIGGER LEVEL potentiometer is offset from 0 V, signals at the Q231 base must compensate for the offset before causing trigger action. Through use of the TRIGGER control, both TRIGGER LEVEL and TRIGGER SLOPE can be manipulated to select any point along the rising or falling slope of a signal to cause trigger action. If two separate signals of different amplitudes are presented simultaneously to the comparator, R246 (TRIGGER LEVEL) can be set to a point where only the larger of the two signals can cause triggering action, thereby causing the sweep to be triggered at the frequency of the larger signal.

Trigger Multivibrator

Non-automatic Operation. The Trigger Multivibrator is a Schmitt Trigger circuit when operated in the non-automatic mode. When Q253 is conducting, the current through R260 and that through the voltage divider connected to the base of Q263 create a combination of voltages which prevents Q263 from conducting. When the output voltage from the comparator decreases, the Q253 emitter voltage decreases and the collector voltage increases. Q263 is thereby permitted to go into conduction. Q263 emitter voltage rises and Q253 cuts off. The sudden increase of Q253 collector voltage is coupled through R256 and C256, aiding Q263 conduction. The current increase through R262 creates a negative step which is differentiated and applied to the Sweep Gentrator circuit to develop a negative trigger which initiates a horizontal sweep. When the Q253 base voltage returns sufficiently positive, Q253 goes back into conduction, cutting Q263 off. The circuit is then ready for another cycle.

Automatic Operation. When the TRIGGER control is switched to either the + or — AUTO position, the following circuit changes are made: wafer 1F inserts C250 in the Comparator Amplifier output signal path, causing the Q253 DC base voltage to be determined by R251, R252 and R253; wafer 2R inserts C221 in the triggering signal path, placing the Q231 base at ground potential; wafer 1R connects the base of Q239 to ground, simultaneously inserting one of the Trig Auto Caps into the base and collector circuit of Q263. The Trig Auto Cap value is dependent upon the position of the TIME/DIV switch.

In AUTO TRIGGER mode, the Schmitt trigger circuit becomes a free-running multivibrator which will synchronize to any triggering signal having a frequency greater than the multivibrator repetition rate. In the absence of triggering signals from Q231, operation occurs as follows: Assume that Q253 is conducting, Q263 is cut off, and that C270 has no charge on it. Circuit design causes the junction of R257 and R258 to go slightly positive, charging C270. The voltage at the base of Q263 increases in proportion to the voltage "ramp" at the C270-R257-R258 junction, until Q263 is turned on. This increases the voltage at the emitter, turning Q253 off. The rise of Q253 collector voltage is coupled through C256 and R256, aiding Q263 conduction. The resulting current lowers the voltage at the collector of Q263, sending a negative gate to C301 in the Sweep Generator. The negative gate voltage is also coupled through R264, causing C270 to discharge. As C270 discharges, its negative-going voltage ramp is coupled through R257, decreasing the Q263 base voltage. The Q263 emitter voltage follows the base, carrying the Q253 emitter with it. Q253 conducts when its emitter becomes sufficiently negative. The resulting change of Q253 collector voltage is coupled through R256, cutting Q263 off. The cycle then repeats itself.

If a signal is coupled in through C250 during AUTO operation, it will either combine with the voltage ramp to cause switching action, or it will override the ramp and cause switching action by itself.

Consider the AUTO condition existing when Q263 is cut off. A positive-going ramp occurs at the base of Q263. If a negative signal simultaneously appears at the base of Q253, it will be coupled to the emitter, lowering the Q263 emitter voltage. The positive ramp at the base and the negative signal at the emitter combine their effects to increase the emitter-base forward bias, placing Q263 into conduction. In similar fashion, when Q253 is turned off, a positive signal at its base will work in conjunction with the negative ramp at its emitter to turn Q253 on. It should be noted that if both the ramp and the input signal are required to produce switching action, the switching rate will not be much greater than the AUTO frequency, although it will be synchronized to the signal frequency or a sub-multiple of it. This situation occurs when trigger inputs are less than those specified under Trigger Sensitivity at the beginning of this manual.

If the signal in from the comparator has a higher frequency than the AUTO multivibrator, and has sufficient amplitude to override the ramp voltage, its effect alone will cause the previously explained switching action, creating negative gates at the frequency of the input signal.

Smaller Trig Auto Caps are substituted when the VOLTS/DIV switch is changed from the .5 to .2 mS positions and from the 50 to 20 μS positions, thus increasing the AUTO repetition rate of the multivibrator. Changing the AUTO repetition rate keeps the sweep intensity relatively constant despite changes in sweep rate.

SWEEP GENERATOR ⟨4⟩

General

The basic purpose of the Sweep Generator is to provide a linear sawtooth voltage to the Horizontal Amplifier. It also controls the minimum time between sweeps and provides unblanking to the cathode-ray tube electron beam during sweep time. When EXT HORIZ operation is selected, the Sweep Generator stops generating sweep voltages and provides continuous unblanking to the cathode-ray tube. The unblanked state can be interrupted by application of an external blanking signal.

Block Diagram Description

Refer to the block diagram contained on the Sweep Generator schematic diagram page. Triggers from the Trigger Generator are received through C301 and applied to the Sweep Gate circuit, which then develops a negative gate. As a result, the Disconnect Diode stops conducting. This allows the Miller Circuit to create a linear sawtooth voltage which is sent to the Horizontal Amplifier. When the sawtooth has sufficient amplitude to provide full horizontal trace deflection, feedback current through the SWEEP LENGTH potentiometer is sufficient to reset the Sweep Gate circuit. The disconnect diode then conducts and the sweep voltage rapidly decreases to its initial value, causing retrace to occur.

The sweep must start at the same DC quiescent voltage level for each sweep, or horizontal jitter will appear. The same signal that causes retrace is therefore sent to the Holdoff Circuit to block triggers from the Sweep Gate until the Sweep Generator circuit has stabilized. The holdoff time is controlled by capacitors which are selected by the various positions of the TIME/DIV switch.

The electron beam is allowed to strike the face of the cathode-ray tube only during sweep time by connecting the

Sweep Gate output to the Unblanking Amplifier. The cathode-ray tube is thereby unblanked when the sawtooth starts rising and is turned off at the instant retrace is initiated. Unblanking can be disabled by injection of a positive signal through the EXT BLANK connector.

Sweep Generator

A knowledge of N-channel Field Effect Transistor (FET) operation and Tunnel Diode switching action is necessary for understanding the Sweep Generator circuit. The FET operation can be understood by simply comparing a triode vacuum tube to it, with the cathode, grid and plate comparing to the source, gate and drain respectively. Like the vacuum tube, the FET has high input impedance and only leakage current flows in the gate circuit.

Refer to the tunnel diode voltage-current graph contained in Fig. 3-6. A tunnel diode switching circuit is designed to take advantage of the fact that a tunnel diode has two stable states. A tunnel diode operating in its low voltage state to the left of point B will stabilize to a point on the curve which satisfies circuit voltage and current requirements. If a signal input causes the voltage or current to exceed the value at point B, the tunnel diode will switch (pass through the unstable negative resistance region) and stabilize to the right of C at a point which will again satisfy circuit requirements. It is then operating in its high voltage state, and will remain there as long as its voltage and current remain greater than indicated by point C. If the current or voltage falls below that value, the diode will again switch through the negative resistance region and return to its low state. The difference between low and high state operating voltages is commonly in the vicinity of ½ volt.

Circuits are designed to permit quiescent operation in either the high or low state at points such as A and D. Transients can then be used to cause switching action to occur, leaving the tunnel diode in the switched state after the transient has expired.

Refer to the schematic diagram of the Sweep Generator (and to the Timing Switch schematic as necessary). A summary of the purpose of components, and their status during a complete sweep cycle, is contained in Table 3-1.

TABLE 3-1

Operating Status of Sweep Generator Components

Component	Purpose	Status[1] Quiescent	Sweep Rising	Retrace	Holdoff
D301	Holdoff Diode	On	Off	Off	Off
D303	Tunnel Diode	Low state	High State	Low state	Low State
D305	Gate Diode	On	Off	On	On
D309	Disconnect Diode	On	Off	On	On
D342/D343	Trigger Disabling Diodes	Off	On	On	Off
D350	Blanking Diode	On	Off	On	On
D353	Unblanking Diode	Off	On	Off	Off
Q305	Sweep Start/Stop Switch	Off	Saturated	Off	Off
Q311, Q317, Q326	Sweep Amplifiers	On	On	On	On
Q343	Quiescent Position Switch	Saturated	Off	Off	Saturated
Q356	Unblanking Switch	Off	On	Off	Off
Q363	Unblanking Amplifier	Off	On	Off	Off
Q370	Plate Charging Switch	Off	Saturated	Off	Off
Q373	Plate Discharging Switch	Saturated	Off	Saturated	Saturated

[1]Shaded areas indicate deviation from quiescent condition.

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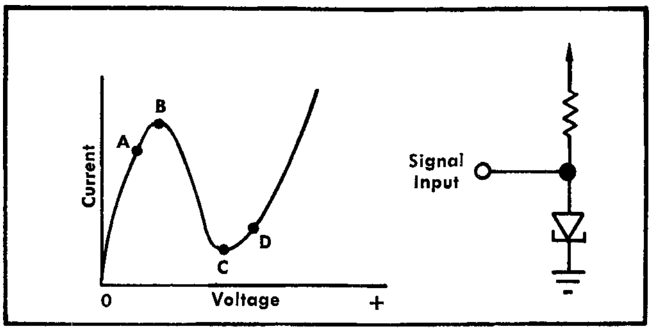


Fig. 3-6. Tunnel diode current-voltage graph and simplified circuit.

Interaction requires that the circuit be explained as one unit, rather than as individual sections. The explanation starts with a trigger being received during quiescent circuit conditions, and goes through a complete cycle of operation.

Sweep Generation. The negative gate from the Trigger Generator is differentiated by C301 and the Sweep Generator input circuitry. The negative triggers thus developed cause increased conduction through D301 and D303. This current increase switches D303 to its high state, where it remains because of the R303 holding current. See Fig. 3-7 (A), (B) and (C). The resulting negative gate causes D305 to cut off, allowing the emitter of Q305 to go sufficiently negative for Q305 to saturate. R305 current (which was flowing through D305) now flows through Q305 and R304. The collector voltage of Q305 goes negative and stops D309, Q343 and D350 from conducting. See Fig. 3-7 (D). (Q343 has been in saturation with its base-emitter junction acting as a diode, connecting the collector of Q326 to the gate of Q311, via D309.) When Q343 cuts off, its positive-going collector voltage causes D342 and D343 to conduct, charging C340 and C342. The resulting positive voltage is coupled through R301, back biasing D301 so that triggers cannot pass through it until the sweep cycle has been completed. See Fig. 3-7 (G), (H) and (B).

When Q305 causes D309 to stop conducting, the Miller Circuit goes into operation as follows: R330 (timing resistor) current, which had been flowing through D309, now charges C330, attempting to make the lower plate and the gate of Q311 go more negative. See Fig. 3-7 (E). The resultant positive-going sawtooth signal at the Q311 drain increases the current drive to Q317. This causes a positive-going sawtooth voltage to be developed at the Q326 collector. See Fig. 3-7 (F).

The Q326 collector voltage is applied to the upper plate of the Timing capacitor, C330. The upper plate of C330 goes positive at almost the same rate as the negative charge accumulates on the lower plate, keeping the lower plate at a relatively constant voltage with respect to ground. This results in an extremely small (about $\frac{1}{2}$ mV) change across R330 during sweep time, keeping the R330 current constant. The constant current charges C330 at a constant rate, creating an extremely linear sweep voltage.

During generation of calibrated sweeps, the selected timing resistor (R330) is connected directly to —5 V. When the VARIABLE control (R334A) is moved from the CAL position, the voltage applied to R330 is decreased. The resulting increased time required to charge C330 causes a decrease in sweep rate (larger time/div value) from that indicated by the TIME/DIV switch.

Sweep Retrace. The positive-going Q326 collector voltage causes an increasing amount of current to flow through R346 and SWEEP LENGTH potentiometer R347. This causes the current through D303 to decrease, because R303 current is relatively constant. D303 switches back to its low state as soon as its current drops below the amount required to hold it in its high state. See Fig. 3-7 (C). The setting of R347 determines the output voltage (and therefore the sweep length) required to cause D303 to switch to its low state. D305 then goes into conduction, turning Q305 off. The positive signal at the Q305 collector enables D309 and D350. The positive potential coupled through D309 to the gate of Q311 causes the output at Q326 to drop until the voltage at the emitter of Q343 is low enough to permit Q343 to go back into saturation. See Fig. 3-7 (D), (E), (F), (G). The output voltage feedback through the base-emitter junction of Q343 and D309 will cause the output voltage to stabilize at its quiescent value.

Holdoff time. When Q305 cuts off and retrace is completed, the current from R344 again passes through Q343, saturating it. D342 and D343 stop conducting and the C342-R342-C340 junction discharges sufficiently for D301 to conduct and hold D303 in its low voltage state. The RC time of R342, C342 and C340 determines the time required before D301 can again conduct triggers. This delay is referred to as holdoff time. It allows the circuit to stabilize between sweeps, thereby minimizing sweep horizontal jitter. See Fig. 3-7 (G), (H) and (B).

Oscillation of the Sweep Generator circuit is prevented by the addition of C313, C316, R316 and C321.

Unblanking. The CRT is blanked during quiescence by the following conditions: Current from R355 flows through the Q373 base-emitter junction, saturating Q373. The voltage at the bottom of R355 sets the emitter of Q356 at about +0.6 V. The cathode of D353 is held at about 0 V by the potential on the base of Q343. The 0.6 V across D353 and Q356 base-emitter junction is not sufficient to cause forward conduction and Q356 remains cut off. The voltage at the emitter of Q363 is also set by the Q373 emitter-base junction and is not sufficiently negative to cause Q363 to conduct. This causes the base and emitter of Q370 to both be at +100 V, so that Q370 is also cut off. With Q370 cut off and Q373 saturated, the voltage at the Q370 collector is very near 0 V. This is connected to one of two opposing unblanking plates, the other of which is at +100 V whenever the Oscilloscope is on. The electrostatic effect of the plates during the unbalanced condition prevents the beam from striking the face of the cathode-ray tube.

When a trigger signal causes Q305 to conduct, the negative gate which is coupled through D350 causes D353 and Q356 to go into conduction. The emitter voltage of Q356 decreases, turning Q373 off and Q363 on. Current through R363 lowers the Q363 collector voltage by about 0.6 V, saturating Q370. This effectively connects the cathode-ray tube unblanking plate to +100 V, permitting the beam to strike the face of the CRT.

Application of a positive signal of 5 V or more at the EXT BLANK connector J350 will turn off Q356, again causing

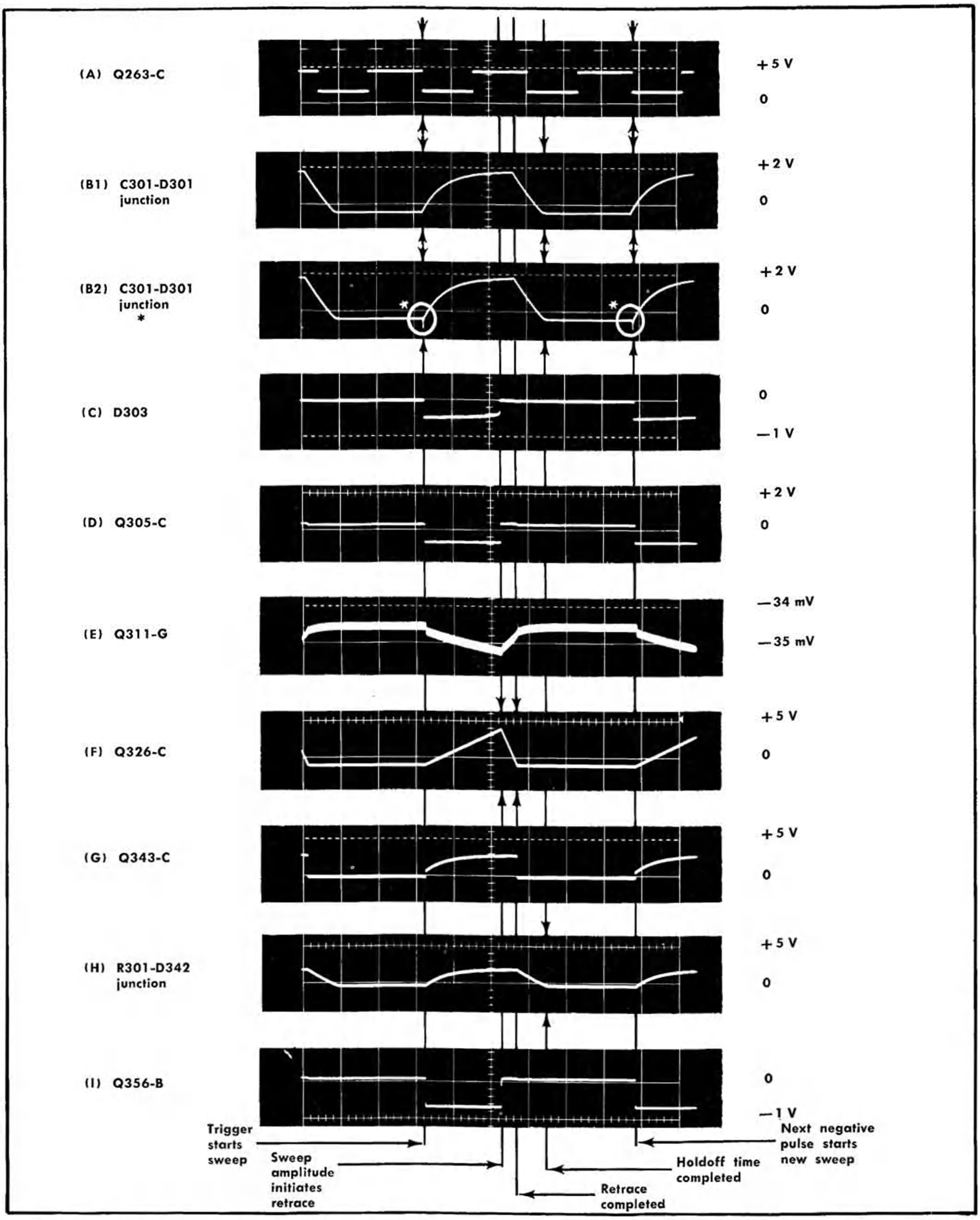


Fig. 3-7. Sweep Generator waveform analysis. Type 323 Oscilloscope sweep rate .1 ms/DIV. VOLTS/DIV switch set at 5 DIV CAL. Waveforms obtained with Type 547 Oscilloscope and C12 camera system; deflection factor 0.5 ms/div. *(B2) is the same as (B1) except that "B intens by 'A' " was used to show the triggers which initiate the sweep. 'A' Time/cm was set at 0.1 μs/div and a double exposure was taken, intensifying one of the trigger pulses each exposure.

blanking to occur. Protection from large external blanking signals is provided by R351 and D351. Signals at the EXT BLANK connector in excess of approximately +8 V will cause D351 to go into conduction, limiting the signal at D353 to +5.6 V.

When the end of the sweep initiates retrace, Q305 turns off and D350 goes into conduction. This turns D353 and Q356 off and the circuit returns to its quiescent condition. C353, C361, C362 and C364 improve circuit response sufficiently to cause the electron beam to be blanked before an appreciable amount of retrace occurs.

Residual voltage exists in the high voltage power supply for a brief period after the Oscilloscope is turned off. As long as some voltage remains in the +100 V power supply, it appears on the non-driven unblanking deflection plate. It is also applied to the base of Q373 through contacts of the POWER switch and R369. This keeps Q373 in conduction, grounding the driven unblanking deflection plate, thereby keeping the CRT blanked while the high voltage power supply discharges and the CRT filament cools.

EXT HORIZ Operation. When EXT HORIZ operation is selected by the TIME/DIV switch, R340 is connected in parallel with R342. The collector of Q326 is connected directly to the gate by Q311, bypassing timing capacitor C330. R330 (the timing resistor) becomes disconnected from the circuit. The parallel combination of R340 and R342 switches D303 to its high voltage state, turning Q305 on. Unblanking occurs, but removing the timing resistor and short circuiting the timing capacitor prevent a sweep from being generated. The intensity should be turned down under this condition to provide optimum viewing and to conserve operating power, thereby lengthening the operating cycle during internal battery powered operation.

HORIZONTAL AMPLIFIER ⟨6⟩

General

The Horizontal Amplifier accepts a horizontal sweep voltage from the Sweep Generator, amplifies it and applies the resulting push-pull signal to the horizontal deflection plates of the cathode-ray tube. During EXT HORIZ operation, the input from the Sweep Generator remains constant, allowing EXT HORIZ input signals to be amplified and applied to the horizontal deflection plates. The overall gain of the amplifier is normally about 50 and increases by a factor of 10 during ×10 HORIZ MAG operation.

Block Diagram Description

Refer to the block diagram on the Horizontal Amplifier schematic page. The horizontal sweep signal received from the Sweep Generator passes through a horizontal gain calibrating resistor, is amplified by the Output Amplifier and is then applied to the left deflection plate of the cathode-ray tube. The Output Amplifier is an operational amplifier whose feedback circuit is modified when ×10 HORIZ MAG operation is selected.

The signal at the left deflection plate drives the Output Inverter, which supplies the signal to the right deflection plate. The Output Inverter is also an operational amplifier and has a gain of one under all operating conditions.

As the electron beam is moved from left to right across the face of the cathode-ray tube, the Output Amplifier circuit current decreases as its voltage output decreases. Simultaneously, the Output Inverter current increases in step with its output voltage. During retrace the reverse is true. The Current Control Circuit exchanges the current between the two circuits to provide optimum operating efficiency.

The quiescent beam position (and therefore the horizontal area through which the beam moves) can be selected by the POSITION control, and it is normally set to cause the sweep to start at the first marking at the left of the graticule. During ×10 HORIZ MAG operation, the POSITION control range permits any 10% of the normal sweep to be presented as a 10 division sweep.

When EXT HORIZ operation is selected by the TIME/DIV switch, the Horizontal Amplifier circuit operates exactly as previously explained, except that the sweep signal from the Sweep Generator circuit has been replaced by an externally applied signal. When the EXT HORIZ VAR control is fully clockwise, R334B is bypassed. The external horizontal gain will decrease to 1/10 its previous value when the control is rotated fully counterclockwise.

Output Amplifier and Output Inverter

Refer to the schematic of the Horizontal Amplifier. Signals from the Sweep Generator cause current flow through R401 (×1 GAIN) and R402. A very small percentage of this current passes through the base-emitter junction of Q415, which causes a current drive signal to be sent to the bases of Q420 and Q427. This causes an output voltage change (at the collector of Q427) with a polarity opposite to that of the signal voltage change applied to R401. The output voltage causes almost all of the R401, R402 signal current to flow through R430 and R431 except for the small amount of Q415 base-emitter signal current. Because of the feedback configuration, the base of Q415 remains very close to the 0 V potential dictated by D416 and the base-emitter junction of Q415. The signal from the collector of Q427 drives the left deflection plate of the cathode-ray tube and also drives the Output Inverter amplifier.

R454, R457 and Q459 form an operational amplifier circuit with a gain of one, R457 (R_F) being equal to R454 (R_i). The inverted signal output from the Q459 collector provides the right deflection plate with a signal which is equal and opposite to that applied to the left deflection plate. C454 and C457 provide an adjustable high-frequency current path to insure linear high frequency sweep operation.

The current flowing through the summing node at the base of Q415 determines the circuit output voltages, and therefore the beam position. The POSITION control modifies this summing node current by using a dual potentiometer arrangement for coarse and fine positioning. The fine potentiometer (R409B) has its pickoff voltage connected through

a large resistor to the summing node. The POSITION control can move the fine potentiometer wiper 30° independent of the coarse potentiometer, moving the trace 1 division in ×1 mode, and 10 division in ×10 mode. Continued movement of the POSITION control causes both of the wipers to move. Combined movement of the coarse and fine wipers permits an approximate 14 division total horizontal movement range in ×1 mode.

The R404-R405 circuit compensates for changes in the sweep start position which would otherwise occur as a result of changing sweep rates. Refer back to the Sweep Generator schematic. It was previously stated that the sweep start reference was established by connecting the collector of Q326 to the gate of Q311 by way of D309 and the emitter-base junction of saturated Q343. The D309 current flows through the timing resistors. Smaller resistors are inserted when faster sweep rates are selected. This causes the D309 current (and therefore the voltage across it) to increase slightly with increases in sweep rates. Q311, Q317 and Q326 respond to these slight changes and the quiescent output voltage changes accordingly.

The slight increase in quiescent voltage from the sweep generator during fast sweep rate selection causes an increase in current through R401 and R402. This current change is compensated for by decreasing the resistance of the R404-R405 circuit as the sweep rate is increased. The sweep starting position, therefore, remains relatively independent of sweep rate.

When ×10 HORIZ MAG operation is selected, a current divider network is connected into the feedback circuit in such a manner that only one-tenth of the R430-C432 feedback current passes through R431-C433, with the remaining current flowing in the path provided by R433, R437, R438 and R439. This reduction of degenerative feedback current requires that the output voltage be ten times as large as in the ×1 situation to provide sufficient feedback current to balance the input signal at the base of Q415. Due to output voltage limitation, this can only occur as the input sweep voltage passes through slightly more than 10% of its sweep sawtooth.

An instant exists during a magnified sweep when all the R430 feedback current flows to the summing node at the base of Q415, and no current flows through R433. This occurs when the voltage at the R430-R431 junction is equal to the voltage at the R437-R438 junction. The sweep position is then totally under the control of the sawtooth sweep voltage, just as it is during ×1 sweep presentation. This is the magnified sweep registration point, or the point on the CRT at which the same instantaneous presentation will appear during either ×1 or magnified sweep. R439 (SWP MAG REGIS) permits adjustment of the R437-R438 junction voltage, so that this registration point will occcur at the graticule center vertical line. When R439 is properly set, the 1 division of horizontal presentation which straddles the center graticule vertical line during ×1 operation will be magnified and appear as a 10 division display when the ×10 HORIZ MAG knob is pulled out. Any 10% portion of the sweep sawtooth can be displayed as a 10 division sweep during ×10 HORIZ MAG operation by adjusting the Horizontal POSITION control.

R433 (×10 GAIN), which is located in the feedback current shunt path, permits adjusting the ×10 feedback current to provide calibrated ×10 HORIZ MAG sweep presentations. R433 must be adjusted after R439 (SWP MAG REGIS) because R439 also affects the impedance of the shunt feedback path.

Current Control Circuit

Q440, Q450, and their associated resistors, diodes and capacitors make up the current control circuit. The following conditions exist during quiescence, when the electron beam is deflected to the left edge of the CRT graticule:

+160 V exists on the left deflection plate while +10 V is applied to the right plate;

D442 sets the base of Q440 at +168 V, and the Q440 emitter at about +168.6 V;

The 6.4 V across R441 causes about 425 μA of current to flow through R441 and the Q440 collector, where it splits to provide operating current for Q427, and the current which the +160 V demands through R430 and R454;

The base of Q450 is at approximately the same potential as the base of Q440, because of the small voltage across the R444-R446 voltage divider;

The emitter of Q450 is at about the same potential as the emitter of Q440, with essentially no current flowing through R451;

Approximately 150 μA of current is demanded through R450, passing through Q450 and providing operating current for Q459, plus the small amount of current required by the 10 V across R457.

When the trace is positioned to the right edge of the graticule, conditions are changed as follows:

The voltage on the left deflection plate is at about +10 V, while that on the right plate is about +160 V;

The current demanded through R430 and R454 decreases in proportion to the voltage decrease, thus demanding less current from Q440;

The voltage across R446-R444 increases to about 160 V, lowering the base voltage and increasing the drive to Q450;

The Q450 emitter voltage follows its base voltage, creating an unbalance across R451;

The unbalance across R451 causes sufficient current to flow through R451 and Q450 to supply the current re- by the +160 V across R457.

Note that only a very small change of voltage (about 0.5 V) occurs across R450, and its current remains relatively constant. Also note that R441 current remains constant under the two conditions, with the increased current demand of one circuit being compensated for by the decreased demand of the other circuit. Thus, with current shifting from the Q440 side to the Q450 side of the amplifier, demands on the +175 V power supply remain constant.

During fast sweep operation, the lowered impedance of C446 permits a greater portion of the left deflection plate voltage change to be applied to the base of Q450. The

emitter of Q450 follows the base down until D452 conducts and supplies additional current through Q450 to enable rapid charging of the capacitance associated with the deflection plate.

POWER REGULATOR AND CRT CIRCUIT ⟨7⟩

General

The Power Regulator converts DC voltage from the Power Pack into the various operating voltages required by the Oscilloscope. Employing a blocking oscillator, a flyback-type transformer, rectifiers and filters, it develops the following voltages: + and —5, +9, +14, + and —100, +175, and —1900 V DC, and 0.6 V AC. The +9 and —100 V supplies are used only within the regulator circuitry, and the 0.6 V AC supplies the CRT filament power.

Block Diagram Description

Refer to the block diagram contained on the Power Regulator and CRT Circuit schematic page. When the POWER switch is closed, the Blocking Oscillator goes into operation, alternately causing the Energy Storage Switch to turn on and off. When the Energy Storage switch conducts, current flows through T538 primary, storing energy in the transformer. When Q529 stops conducting, the energy stored in T538 is delivered to the secondary windings, providing power to the previously mentioned supplies.

A Feedback Circuit, an Error Amplifier (Q515) and a Blocking Oscillator Control (Q518) circuit combine to determine the frequency at which Q525 operates. Initially, input power is applied through a Start and Reference Circuit and a summing network to the Error Amplifier. Current flows through Q518, permitting the Q525 circuit to oscillate. The +9 V Zener reference (developed in the transformer secondary) feeds back to the Start and Reference Circuit, where it over-rides the input voltage which started the oscillator. When the —100 V supply builds up, its feedback current flows through the summing network to offset the reference current from the +9 V Zener reference. A slight difference between the +9 V and —100 V feedback currents provides a drive current to the Error Amplifier, holding the Blocking Oscillator at its required frequency.

When CRT intensity is at a minimum, practically no cathode current flows, and a minimum amount of power is required by the high-voltage circuit. As CRT intensity is increased, cathode current increases. The CRT cathode voltage starts to diminish, due to the increased drop across the high-voltage multiplier components. A CRT Cathode Current Sense circuit is designed to counteract this voltage loss by sending proportional changes of feedback current to the summing point. The Error Amplifier and Blocking Oscillator Control circuits cause the Blocking Oscillator to decrease its frequency. The Energy Storage switch then stays on for longer periods of time, delivering more energy to the T538 primary. The additional high voltage power required by the increased cathode current is thus made available.

Blocking Oscillator Operation

Refer to Fig. 3-8. When power is applied, a positive voltage appears at the collectors of Q525 and Q529, at the emitter of Q518, and at the base of Q515. Q515 conducts and supplies Q518 with base-emitter current, turning Q518 on. Q518 collector current flows through D523 and turns Q525 on. The Q525 collector current passes through T525 primary and the resulting regenerative feedback transformer action puts Q525 and Q529 into saturation. When the Q525 collector current reaches β times the Q518 current, the rate of change of current through T525 decreases, decreasing the signal coupled into the Q525 base circuit. Q525 decreases conduction. The accompanying decrease of current through T525 induces a negative signal into the base circuits of Q525 and Q529, turning them off. As Q518 current increases, Q525 "on" time increases, and repetition rate decreases.

The collapsing magnetic field that occurs when Q529 turns off causes a large positive voltage at the Q529 collector. This charges C531 through D531. When Q529 again saturates, C531 attempts to discharge through D533, keeping C533 charged up to approximately —100 V.

Q518 current is controlled by Q515 collector current, which is established as a function of +9 V reference in combination with the —100 V and cathode current sensing feedback. As CRT cathode current increases, the voltage developed across R572 increases, causing an increase in Q515 and Q518 current. The resulting increase in forward bias keeps Q525 conducting longer, stores more energy in T538 and delivers more power to the secondary of T538.

The longer Q525 "on" time causes the charge on C533 to become more negative. The resulting increase in feedback through R534-R535 offsets the cathode current feedback voltage (from R572) at the base of Q515, stabilizing the circuit. This action prevents an appreciable change of high voltage from occurring as a result of increased CRT current.

D516 temperature-compensates Q515 and sets its emitter at —0.6 V. D523 protects the base circuit of Q525 from large negative spikes which develop in the secondary of T525 when Q525 turns off.

A further understanding of circuit operation can be obtained by studying the idealized waveforms (Fig. 3-9) with respect to the points indicated in Fig. 3-8.

Refer to the Power Regulator and CRT schematic. D521 protects the collector circuit of Q518 by limiting positive transients to the value of the input supply voltage. D525 protects Q525 by limiting transients to +100 V at its collector. C526 bypasses R526 to speed up the Q529 switching action. R524 forms part of the Q525 base-biasing circuit. C512 and R512 are decoupling components. C529 and L501 perform the dual function of filtering input pulses during AC operation, and minimizing radiation out of the power supply line.

+100 V Power Supply

When Q529 is on, energy is being stored in the magnetic circuit of T538. When Q529 turns off, the changing magnetic

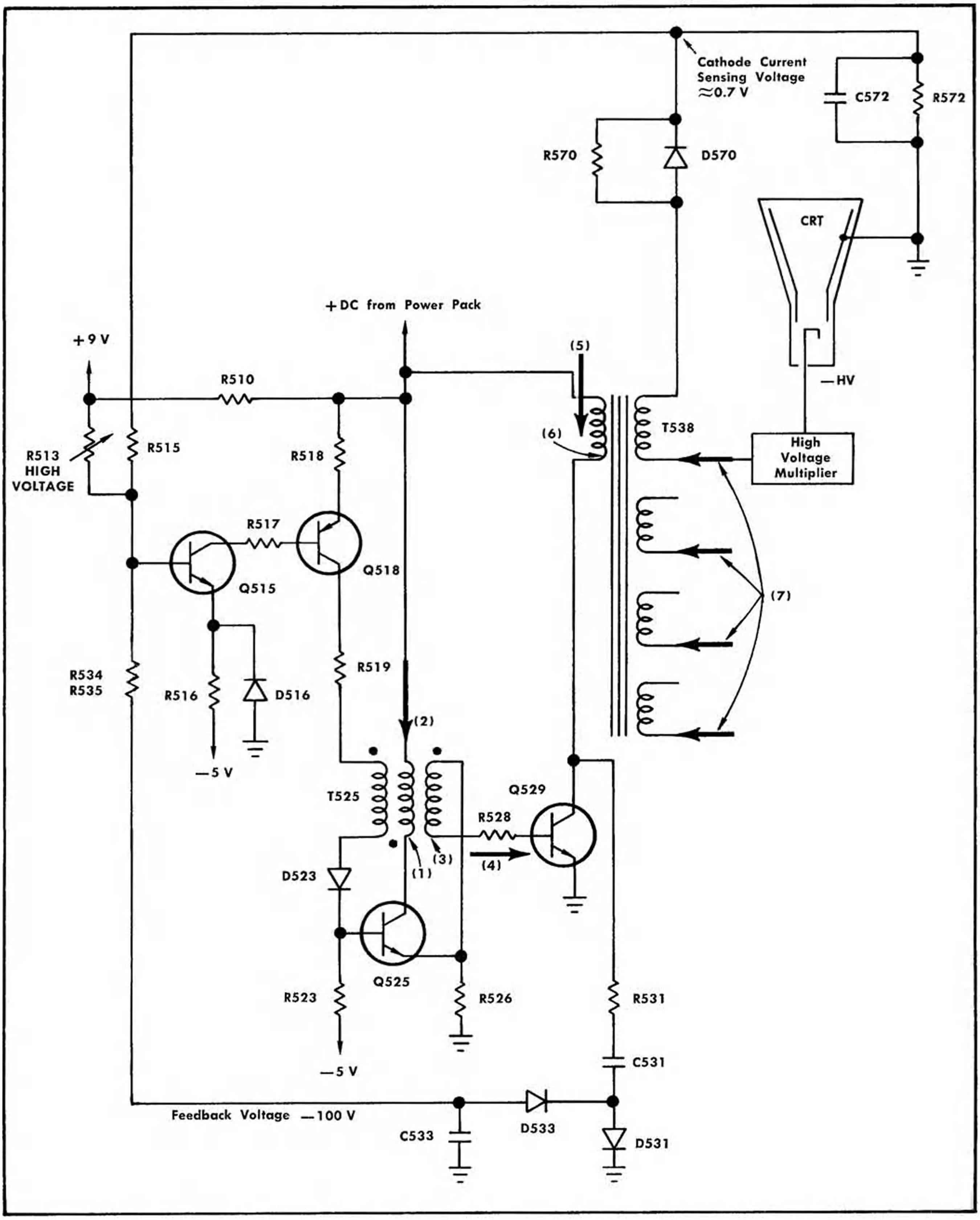


Fig. 3-8. Blocking Oscillator, simplified.

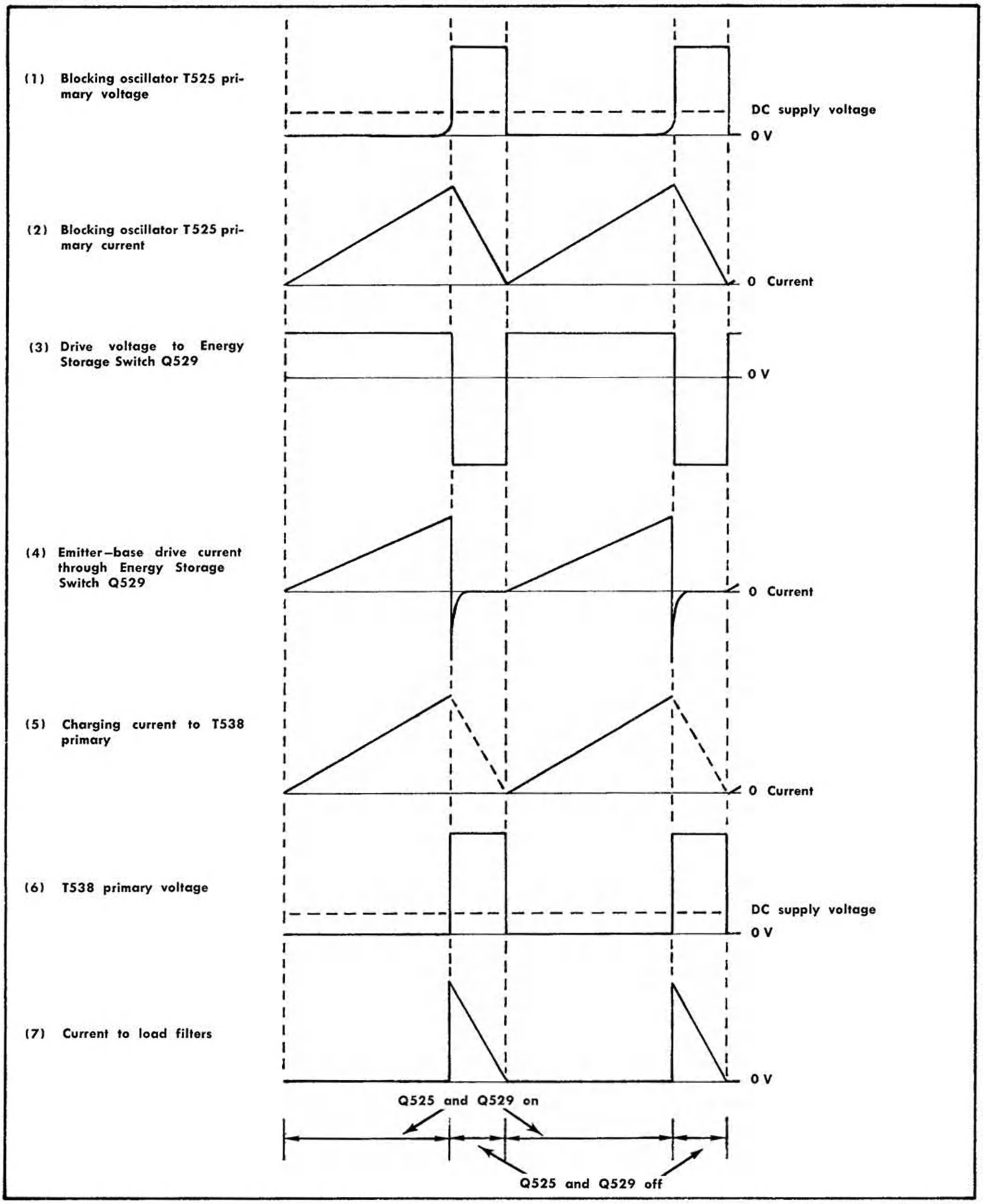


Fig. 3-9. Idealized waveforms referenced to the Blocking Oscillator simplified diagram, Fig. 3-8.

field causes current to flow from the top of the winding, through D543, causing C543 to charge up to approximately +100 V.

+175 V Power Supply

A secondary winding of T538 has one side referenced to the 100 V winding pickoff point and the other side connected to D540. During the time the primary field is collapsing, voltage is induced into this secondary, adding its value to that at the +100 V pickoff point. Current flows through D540 and R541, developing +175 V across C540 and C541.

+14 V and +9 V Power Supplies

Two secondary windings are connected in series-aiding to provide current through D545 and C545 to generate the +14 V power supply. A 9 V Zener diode, D547, uses this 14 V supply to provide the +9 V reference used in the power supply. The remaining 5 V is dropped across R547.

High Voltage Power Supply

A higher turns-ratio secondary winding drives the High Voltage Multiplier which consists of D575 and C573 through C579. The multiplier has 3 negative high-voltage taps: one at —1900 V which supplies the CRT cathode; one at —2250 V supplying the INTENSITY control circuit; and one at —1200 V for the FOCUS circuit. The —1900 V tap is connected into the CRT directly-heated cathode circuit in a manner that keeps the AC filament voltage from changing the cathode potential with respect to the grid, thus eliminating CRT intensity changes. The INTENSITY LIMIT control, R583, is an internal adjustment which sets the minimum difference voltage which can exist between the control grid and cathode. This avoids cathode damage caused by excessive cathode current.

The least negative voltage taken from the High Voltage Power Supply appears at CRT pin 13, the focus anode. The setting of the FOCUS potentiometer, R581, in combination with ASTIG potentiometer R597, determines the sharpness of the trace presentation. Only the FOCUS control is used during routine operation, and it is capable of providing a sharp trace at any intensity setting once the ASTIG control has been properly set.

+5 V Power Supply

The +5 V Power Supply is dependent upon the 9 V reference supply and upon the T538 secondary winding which supplies power through diodes D549 and D550. C550 becomes charged up to nearly the peak value of the output of the secondary winding, and then determines the voltage at the emitter of series-regulator Q558. This dictates the voltage at the base of Q558, which then determines the voltage at the base of Q557. The current through R557 is therefore a fixed value, determined by the difference between the 9 V reference supply and the charge on C550. It may be noted that current through R558 is also fixed, being dependent upon the voltage at the base of Q558.

Error sensor Q555 constantly compares a selected portion of the 9 V reference supply against the +5 V output. This comparison determines the collector current of Q555. Any changes of Q555 collector current must be accompanied by equal and opposite changes of Q557 emitter-base current. This controls the total Q557 emitter current. Any changes in it must be accompanied by equal and opposite changes in Q558 base-emitter current. This controls the conduction of Q558. For example, if the +5 V supply tends to increase, Q555 decreases conduction, which decreases Q558 current drive. Q558 decreases its conduction and more voltage is dropped across it, keeping the +5 V output within limits. The +5 V output is filtered by C559 and L559 before being applied to external circuits.

—5 V Power Supply

The output of the +5 V Power Supply is used as the reference for the —5 V supply. The —5 V supply is derived from the output of a T538 secondary winding which is rectified by D560 and D561, and developed across C560. This voltage determines the voltage at the base and emitter of Q567 and Q569. Current through R562 and R568 therefore remains relatively constant. A comparison between the —5 V output at the collector of Q569 is made against the +5 V supply, and a voltage near —0.6 V is applied to the base of Q562. If the —5 V supply tends to go positive, current through Q562 decreases. This decreases the Q567 emitter-base current, which decreases its collector current. The Q569 emitter-base current increases, causing an increase in Q569 collector current, keeping the —5 V supply within design limits.

CRT Circuit

+100 V appears at pin 5 whenever the Oscilloscope is energized. Pin 9 has 0 V applied except during sweep time or external horizontal operation, during which time +100 V is applied. When the voltage at pins 5 and 9 are unbalanced, the CRT beam is deflected into the pin 9 plate and cannot strike the CRT phosphor. When +100 V is applied to both plates, the deflection effect is nulled, and position control is exercised by the horizontal and vertical deflection plates.

The GEOMETRY control adjusts for a minimum amount of bowing of vertical and horizontal lines, regardless of the area to which they are positioned.

The TRACE ROTATION potentiometer (R592) controls the current through a trace rotation coil, thus creating a magnetic field through which the CRT electron beam passes. When TRACE ROTATION is properly adjusted, horizontal sweep voltages will cause the trace to follow paths which are parallel to the horizontal graticule lines.

Explanations regarding the remaining CRT elements appear in conjunction with the High Voltage Power Supply description.

Low Battery Sensing Circuit

The Low Battery Sensing Circuit employs a relaxation oscillator (R506, C507 and B509) operating at a frequency of approximately 1 to 2 Hz. When the input power exceeds +6.25 V, Q505 is saturated and the voltage at its collector is not sufficient to fire the neon LOW BATT indicator, B509. When the input falls below 6.25 V, Q505 turns off and C507 charges toward +100 V until B509 fires and discharges C507. The cycle then repeats.

Although B509 will blink in any power mode when the supply is less than 6.25 V, it is of primary concern during internal battery operation. If the Oscilloscope is left energized in the internal battery mode for a considerable period of time after the battery output falls below 6.25 V, the batteries may be damaged to the point where they will no longer be chargeable. If the light blinks during operation with external power, it is advisable to check the input voltage for at least 6 V. The Oscilloscope itself can be used to perform this check. Satisfactory external powered operation can be expected with the power as low as 6 V, even though the LOW BATT indicator is blinking.

POWER PACK ⟨8⟩

The Power Pack contains the battery which supplies the internal power, connectors for applying external AC or DC power, a transformer and rectifiers for AC operation, and a battery charging circuit for recharging the internal batteries from an external AC source. The switching circuitry which selects the power source is also contained in the Power Pack.

Block Diagram Description

Refer to the block diagram contained on the Power Pack schematic diagram page. SW612 is a multiple contact switch which has three positions—EXT DC, TRICKLE CHG and FULL CHG. In EXT DC position, power is routed from the DC input jacks to the Oscilloscope POWER switch, SW501. The internal batteries and the battery charging circuit are disconnected from the rest of the Oscilloscope in this mode of operation.

With SW612 in FULL CHG or TRICKLE CHG position, either AC or internal battery operation is possible. With no AC applied, the batteries supply the power. When AC is applied, the transformer supplies operating power, and provides battery charging power during part of each input half cycle. When the output of the transformer secondary falls below a certain level, diodes disconnect the transformer from the charging circuit and the battery supplies the operating power until the power supply diodes again conduct. In effect, the battery acts as a large filter capacitor for Oscilloscope operation when AC is applied. In the AC mode of operation, a reference voltage is developed across D649. The Comparator Amplifier compares a portion of this reference to the voltage generated by the battery charging current which flows through R615. The Comparator Amplifier output controls the Driver Amplifier, which controls the conduction of the Series Regulator Q617, thereby determining the battery charging current. The battery charging circuit is independent of the POWER switch, operating whenever AC power is applied.

Battery Charger

Refer to the Power Pack schematic. When AC power is applied, the output of the upper secondary winding of T601 is rectified by D605 and filtered by C605. The bottom of C605 is connected to the positive side of the battery. The charge on C605 is in series with the battery, and their combined voltage is applied to the R605-D649 combination. D649 provides a 6.2 V reference for battery charger operation.

This 6.2 V reference voltage is applied to R643-R644, setting the Q636 base voltage. This voltage is compared to the Q634 base voltage (average voltage across R615) to determine the division of R635 current between Q634 and Q636.

The lower secondary winding of T601 delivers charging and operating current through full-wave rectifier D610. The positive side of the rectifier is connected to the positive side of the battery, and the negative side is connected through the series regulator circuit to the battery negative side. There is a time internal between pulse peaks during which time D610 does not conduct. See Fig. 3-10 (B). The current from Q634 and Q636 is then shunted to ground through D637 and D638, keeping Q634 and Q636 from saturating.

When the half-cycle output voltage of T601 secondary becomes large enough to overcome the battery voltage, D610 goes into conduction, delivering a negative-going voltage pulse to the battery charging network. R635 current starts to flow through R639, R637 and R638. See Fig. 3-10 (A) and (C). The combination of a negative-going voltage at the emitter of Q621 and the voltage developed across R639 causes Q621 to conduct, supplying current drive to Q620, which supplies current drive to Q617. See Fig. 3-10 (D), (E) and (F).

Q617 goes into conduction once each half-cycle and the resulting current develops a positive pulse across R615. See Fig. 3-10 (G). Voltage divider action causes a portion of each pulse to be developed at the base of Q634. C636 charges up to the average voltage, thus developing the Q634 base voltage. The comparison of this average voltage to that set on the base of Q636 (by CHARGE RATE potentiometer R644) determines how much drive current is provided to Q621. If an increase of line voltage attempts to increase the charging rate, C636 charges to a higher average value, decreasing the drive current to Q634 and Q621. This decreases the drive current to Q617, keeping the R615 charging pulses (and therefore the battery charging rate) within design limits.

It should be noted that even though C636 is charged to the average of the input pulses, almost identical pulses are present at the bases of Q634 and Q636, so that the current division between the two transistors is not upset dur-

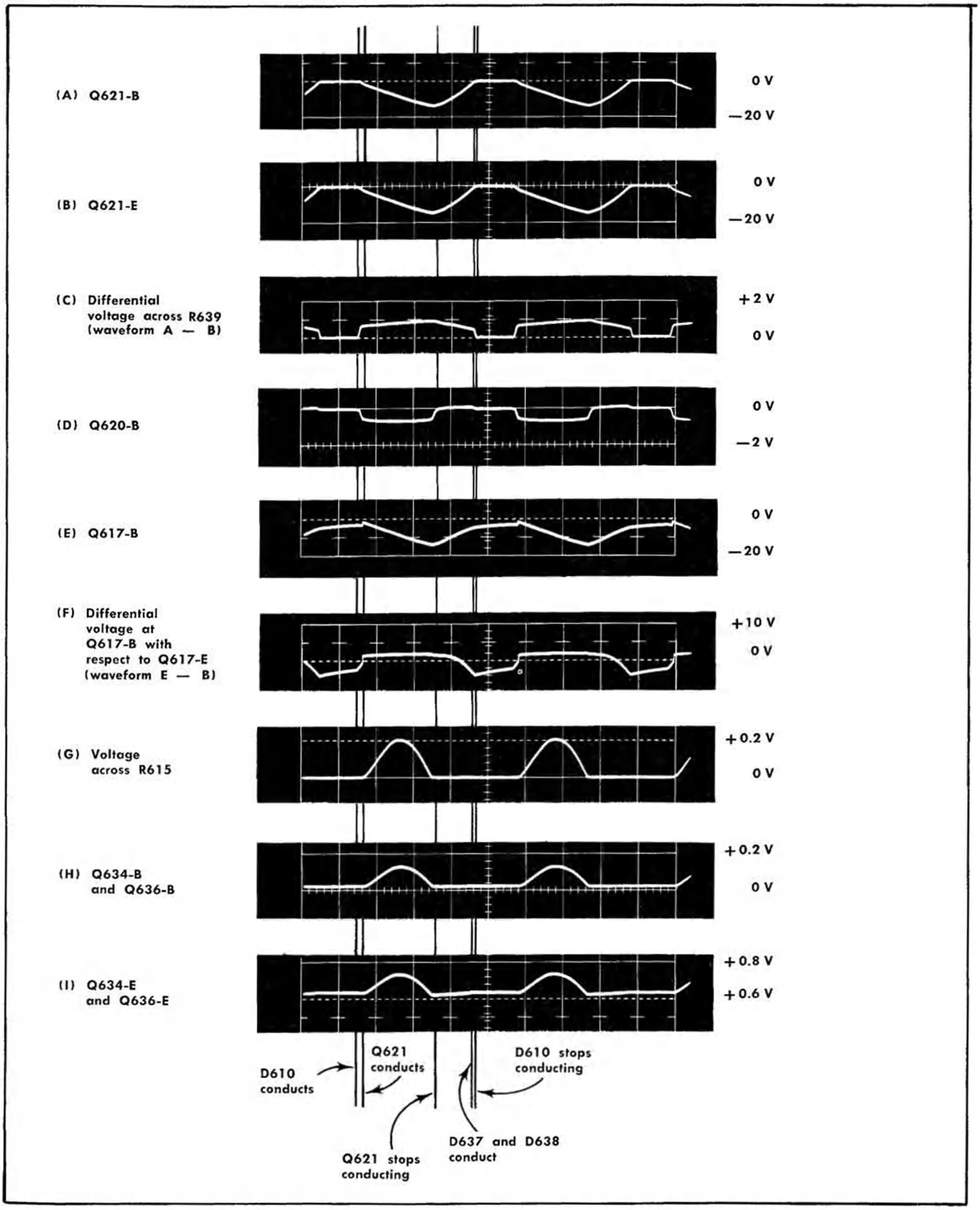


Fig. 3-10. Battery charger waveform analysis during full charge operation with Oscilloscope OFF. Ground is used as reference except for (C) and (F). Waveforms are indicative of fully charged batteries. Amplitudes change with battery charge rate and ON/OFF status of the Oscilloscope.

ing the presence of a charging pulse. See Fig. 3-10 (H) and (I).

During TRICKLE CHARGE operation, R633 provides current to R630. This increases the voltage at the base of Q634 and decreases the current through R639. With less drive, Q621 provides less drive current to Q620, which decreases the drive current to Q617. The current that Q617 delivers to the battery is thereby reduced to a trickle charge rate. See Fig. 3-11 (A).

When the Power Pack is being charged and the Oscilloscope POWER switch is turned on, the base of Q634 is driven negative between charging current pulses. This occurs because the battery reverses current flow through R615 while it supplies the Oscilloscope with power. The net result is that the average charge on C636 tends to decrease, providing more drive to Q634. This permits more current to flow through Q617, keeping the average charge on C636 at its previous value by supplying the battery with additional current to make up for that being drained between half cycles. See Fig. 3-11 (B).

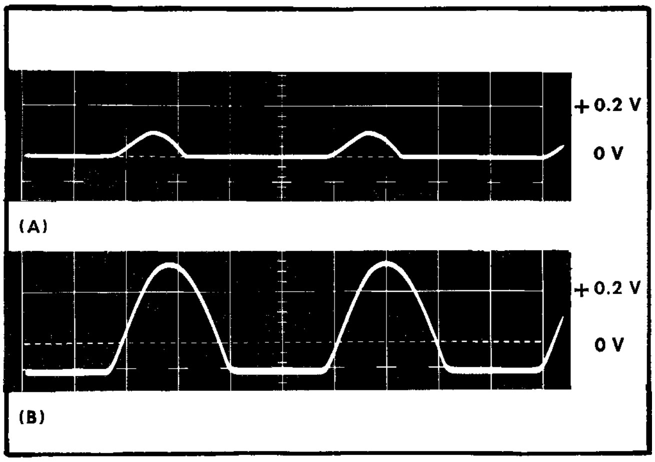


Fig. 3-11. Voltage across R615 during (A) TRICKLE CHG operation with Oscilloscope OFF, and (B) FULL CHG operation with Oscilloscope ON and INTENSITY at maximum brightness setting.

SECTION 4
MAINTENANCE

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

Information contained in this section appears in the following sequence:

- Preventive Maintenance
  - General Information
  - Cleaning
  - Visual Inspection
  - Lubrication
  - Transistor Checks
  - Recalibration
- Troubleshooting
  - Test Equipment
  - General Techniques
  - Troubleshooting Basic Components
  - Troubleshooting Charts
    - General
    - Master Troubleshooting Chart
    - Power Regulator Troubleshooting Chart
    - Trigger Generator Troubleshooting Chart
    - Sweep Generator Troubleshooting Chart
    - Horizontal Amplifier Troubleshooting Chart
    - Vertical Preamplifier and Output Amplifier Troubleshooting Chart
- Corrective Maintenance
  - General
  - Parts Procurement
  - Soldering Equipment and Techniques
- Disassembly and Assembly
- Component Location Illustrations

Cabinet Removal

Cabinet removal and replacement information appears in the Power Pack Operating Procedure which is contained in Section 2, Operating Instructions. The precautions outlined there should be observed to avoid personal injury or equipment damage during cabinet removal or replacement.

PREVENTIVE MAINTENANCE

General Information

The Type 323 Oscilloscope should be cleaned, lubricated, inspected and recalibrated at regular intervals. A recommended schedule for average operating conditions is every 6 months or every 500 hours of operation, whichever occurs first. Additional information regarding maintenance of the Power Pack is contained under the Disassembly and Assembly part of this section.

Cleaning

Cleaning the Type 323 Oscilloscope, in addition to improving its appearance, aids its operation and lengthens its operating life. Dirt on components can result in short circuits. A dry, soft cloth and a soft-bristled brush are recommended for removing loose dirt from the outside of the instrument. Dirt on the inside should be loosened with a soft-bristled brush and removed by using a vacuum cleaner or a stream of low-pressure air. High-pressure air can damage the equipment and should not be used.

WARNING

Use an eye-shield when cleaning with pressurized air.

Hardened dirt should be removed by using a mild detergent and water solution on a cotton-tipped swab or a soft cloth. Remove the Power Pack before using the solution on the Oscilloscope. Avoid excessive use of water. Do not allow water to penetrate any parts. Dry the instrument thoroughly before energizing it. Avoid the use of abrasives and chemical cleaning agents. Protect the oscilloscope from dirt and damage by keeping it covered when not in use.

Soap and water should not be used on the Power Pack unless one lead from the battery pack is unsoldered and taped up. The unit must be allowed to dry thoroughly before reconnecting the lead. The battery compartment should be checked for dirt and corrosion during the maintenance period. Corroded areas should be cleaned with a neutralizing solution of 2% borax and water to prevent further corrosion. Disassembly and Assembly instructions appear later in this section and should be referred to before opening the battery compartment.

Visual Inspection

After cleaning, the instrument should be carefully inspected for defects such as poor connections, damaged parts and improperly seated transistors. Damaged parts require that the cause of the damage be eliminated before operation is resumed.

Lubrication

Keep all moving parts properly lubricated. Using a cleaning-type lubricant on shaft bushings and switch contacts. Lubricate switch detents and screw threads with a slight amount of grease. **Do not overlubricate.** Proper lubricants and lubricating instructions are contained in Tektronix lubrication kit, part no. 003-0342-00. Contact the Tektronix Field Representative if additional information regarding lubricants or lubrication is required.

Transistor Checks

Checking transistors as a preventive maintenance function is not recommended. Circuit performance is thoroughly checked during calibration; unacceptable transistors will be detected at that time.

Recalibration

The calibration status of an instrument should be determined as a part of preventive maintenance for several reasons: 1) The calibration of an instrument changes slightly with age, use and operating conditions; 2) Calibration may be affected during the cleaning process; and 3) Checking the calibration status may reveal troubles which are not obvious during regular operation.

The calibration status can be determined rapidly by accomplishing the Performance Check in section 5. A step-by-step calibration procedure is contained in section 6.

TROUBLESHOOTING

Test Equipment

The test equipment listed here should suffice for most troubleshooting jobs on the Type 323 Oscilloscope.

High Impedance Voltmeter (10,000 Ω/V DC or greater)

Ohmmeter; 1½-V source supplying less than 2 mA of current on the × 1 k scale)

Test oscilloscope (2 MHz bandpass; 25 MHz bandpass for troubleshooting Vertical Amplifier high frequency problems)

Transistor Curve Tracer or Transistor Tester

General Techniques

Proper troubleshooting logic is the most important tool in equipment repair. The following guide provides a logical sequence for analyzing equipment failures:

1. Check all external control settings.
2. Determine that operating procedure is correct.
3. Determine all of the trouble symptoms.
4. Perform a visual inspection.
5. Troubleshoot the circuitry; repair as necessary.
6. Check the calibration status; recalibrate as necessary.

Control Settings and Operating Procedures. Refer to the Operating Instructions section of this manual to verify external control settings and operating procedure.

Trouble Symptoms. After it is confirmed that trouble exists, the response to all exterior controls should be observed. The first-time operation listed in Section 2 can be used for this purpose. All trouble symptoms should be evaluated and compared against each other. Equipment trouble will often create a combination of symptoms that will pinpoint the trouble. A good example of this is power supply trouble, which will usually cause symptoms to occur in otherwise unrelated circuits.

Visual Inspection. In visually examining the Type 323 Oscilloscope, take special note of the area localized by evaluation of symptoms. Look for loose or broken connections, improperly seated transistors, and burned or otherwise damaged components. Repair all obviously defective parts. Investigate the cause of heat damage to components.

Detailed Troubleshooting. If the trouble has not been disclosed and corrected through the procedure outlined, a detailed troubleshooting analysis must be performed. The Circuit Description section, the Schematic Diagrams, the Calibration Procedure, and the Troubleshooting aids contained in this section are designed to expedite troubleshooting.

The Circuit Description section provides a fundamental understanding of circuit operation and is referenced to the Schematic Diagrams. The Schematic Diagrams contain voltage and resistance values and signal waveforms. All specified operating conditions should be duplicated before making voltage or waveform comparisons. In cases where the black numbers and blue numbers on the schematics give conflicting voltage values, the blue numbers should be used.

NOTE

Voltages and waveforms may vary slightly between individual Type 323 Oscilloscopes and are also dependent upon the characteristics of the test equipment used to obtain them. Voltages and waveforms given in the schematics should be checked against each instrument while it is operating properly. Deviations should be noted on the schematics for later reference.

Calibration. Although the calibration procedure is intended primarily for instrument calibration, it can serve as an efficient troubleshooting aid. Since each step is based upon satisfactory performance of the preceding steps, the problem circuit will be encountered before circuits which are dependent upon it.

Troubleshooting Basic Components

Transistors and Diodes

The quantity of semi-conductor devices in the Type 323 Oscilloscope requires that anyone working on it have a general knowledge of semi-conductor operation. Some basic information is presented here to aid in this respect.

Direct Replacement. Once a casualty has been isolated to a specific circuit, the ease of replacing transistors often makes substitution the fastest means of repair. Adhere to the following instructions if the replacement method is used:

Determine that the circuit is safe for the substitute component.

Use only known-good substitutes.

Have only one transistor out of the instrument at a time to avoid mixing them up.

Insert transistors properly, using Fig. 4-13 as a guide.

Check operation after each component is replaced, and be sure to return good components to their original sockets.

If the trouble is not corrected by this procedure, re-check the semi-conductors under operating conditions.

Check calibration after a bad component has been replaced.

WARNING

Voltage, either positive or negative, is often present on the cases of metal-cased transistors when the oscilloscope is energized.

Transistor Troubleshooting. Transistor defects usually take the form of the transistor opening, shorting, or developing excessive leakage. The best means of checking a transistor for these and other defects is by using a transistor curve display instrument such as a Tektronix Type 575. If a transistor checker is not readily available, a defective transistor can be found by signal tracing, by making in-circuit voltage checks, by measuring the transistor resistances, or by the substitution method previously described.

When troubleshooting with a voltmeter, measure the emitter-to-base and emitter-to-collector voltages to determine if the voltages are consistent with normal circuit voltages. Voltages across a transistor vary with the type of device and its circuit function. Some of these voltages are predictable. The base-emitter voltage of a conducting germanium transistor will normally be 0.3 V and a silicon transistor's will normally be 0.6 to 0.7 V. The collector-emitter voltage of saturated transistors will vary between 30 mV and 0.2 V, approximately. Because these values are small, the best way to check them is by connecting the voltmeter across the junction and using a sensitive voltmeter setting, rather than by comparing two voltages taken with respect to ground.

If values less than these are obtained, either the device is shorted or no current is flowing in the circuit. If values are in excess of the base-emitter values given, the junction is back-biased or the device is defective (open). Values in excess of those given for emitter-collector could indicate either a non-saturated device operating normally, or a defective (open) transistor. If the device is conducting, voltage will be developed across resistances in series with it; whereas if it is open, no voltage will be developed across resistances in series with it unless current is being supplied by a parallel path.

An ohmmeter can be used to check a transistor if the ohmmeter's voltage source and current are kept within safe limits. 1½ volts and 2 mA are generally acceptable. Selecting the × 1 k scale on most ohmmeters will automatically provide safe voltages and currents. If the voltage and maximum output current of a specific ohmmeter is in doubt, it should be checked before using it on transistors by connecting the test leads to another multimeter.

CAUTION

A transistor's specifications should be checked to determine maximum allowable ratings before subjecting it or associated circuits to voltage or current higher than that recommended.

Table 4-1 contains the normal values of resistance to expect when making an ohmmeter check on an otherwise unconnected transistor. Fig. 4-13 illustrates transistors and sockets for pin location purposes.

TABLE 4-1

Transistor Resistance Checks

Ohmmeter Connections[1]	Resistance Readings That Can Be Expected When Using the R × 1 k Range (1.5 V ohmmeter operating voltage)
Emitter-Collector	High readings both ways (100 kΩ to 500 kΩ, approximately)
Emitter-Base	High reading one way (200 kΩ or more) Low reading the other way (400 Ω to 3.5 kΩ, approximately)
Base-Collector	High reading one way (200 kΩ or more) Low reading the other way (400 Ω to 3.5 kΩ, approximately)

[1]**Reverse the test lead connections to make the second reading. Reversal of the applied voltage polarity causes the junction to shift between being reverse and forward biased, as indicated by the difference in resistance.**

Field Effect Transistor Checks. The voltage and resistance of field effect transistors can be checked in the same manner as transistors. However, it should be remembered that normal operation in the Type 323 Oscilloscope has the gate-to-source junction reverse biased, in a manner similar to control grid to cathode bias in vacuum tubes. 1½ V and less than 2 mA should be used for ohmmeter checks. Resistance readings should be:

drain-to-source	Less than 500 Ω
gate-to-source and gate-to-drain	400 Ω to 10 kΩ (approximately) in one direction; more than 200 kΩ with leads reversed

Diode Troubleshooting. Checks on diodes (other than Zeners) can be performed in much the same manner as on transistor base-emitter junctions. Germanium diodes should have approximately 0.3 V and silicon diodes should have about 0.6 V across the junction when conducting. Higher readings indicate that they are either back biased or defective, depending on polarity. The ohmmeter precautions pertaining to transistors should also be observed when checking diodes.

Some diodes used in the Type 323 Oscilloscope are color coded to identify the diode type. A blue or pink first band indicates that the next three colors translate to the last three digits of its part number. Diode polarity can be determined by color code position. See Fig. 4-1.

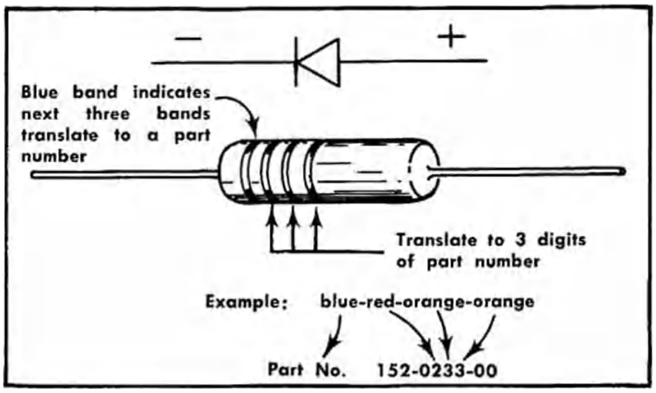


Fig. 4-1. Diode color code related to part number and conducting polarity.

NOTE

The positive side of an ohmmeter voltage source is often connected to the meter common test lead.

Resistors. The same ohmmeter voltage and current precautions observed in transistors troubleshooting also apply when making in-circuit resistance checks. Because semi-conductor devices are present, most resistors in the Type 323 must be disconnected before reliable resistor checks can be made.

The types of resistors found in this instrument vary in accordance with the circuit needs. Composition, metal film and wire-wound resistors are used. Replacement resistors should be of the same type and must be at least as accurate as those originally contained in the circuit to maintain performance standards. The size, location and lead length are often critical because of frequency considerations.

Resistor values are indicated by one of three methods in the Type 323 Oscilloscope:

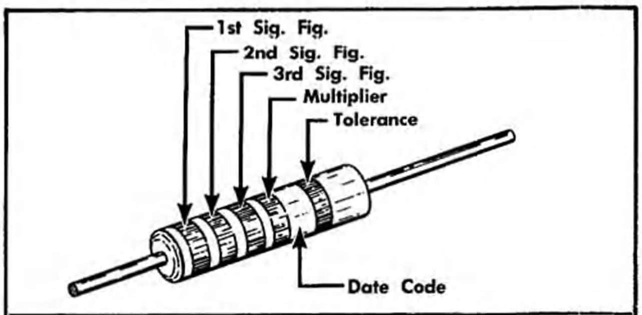
3 color bands (digit, digit, multiplier—tolerance)

4 color bands (digit, digit, digit, multiplier—tolerance)

Numbers printed on wire wound and metal film resistors

The first two methods translate to the IEEE color-code equivalent and are illustrated in Fig. 4-2.

Wiring Information. Insulated wires in the Type 323 Oscilloscope are color coded to make wire tracing easier. When it is necessary to disconnect several wires from components, record the wire color coding. In case of doubt in reconnecting wires, use an ohmmeter to insure selection of the proper lead.



Color	1st Sig. Fig.	2nd Sig. Fig.	3rd Sig. Fig.	Multiplier	Tolerance (±) %
Black	0	0	0	1	—
Brown	1	1	1	10	1
Red	2	2	2	100	2
Orange	3	3	3	1,000	—
Yellow	4	4	4	10,000	—
Green	5	5	5	100,000	0.50
Blue	6	6	6	1,000,000	0.25
Violet	7	7	7	10,000,000	0.10
Gray	8	8	8	100,000,000	0.05
White	9	9	9	1,000,000,000	—
Gold				0.1	5
Silver				0.01	—
No Color					10

Fig. 4-2. Resistor color coding.

Switches. Rotary switch wafers are coded with a number and a letter on the schematic diagrams. The number indicates the wafer position in the switch assembly, counting from the front (mounting end). The letters "F" and "R" indicate whether the front or rear of the wafer performs the switching action. For example, a switch section designated 2R is contained on the rear of the second wafer as viewed from the front of the switch.

In addition, each wafer contact is numbered as follows:

VOLTS/DIV switch and TRIGGER switch—Contacts are numbered from 1 through 12, starting at the lower mounting post and counting clockwise when viewed from the front and counterclockwise when viewed from the rear.

TIME/DIV switch—Contacts are numbered from 1 through 18, starting at the upper mounting post and counting clockwise when viewed from the front and counterclockwise when viewed from the rear.

Individual switch wafers or mechanical parts of rotary switches are normally not replaced. If a switch is defective, replace the entire assembly. Wired and unwired replacement switches are available; refer to the Parts List for part numbers. When a switch is removed, make careful notation of the lead connections for installation reference.

Troubleshooting Charts

General. The troubleshooting charts contained here are designed to permit finding the mal-functioning circuit with a minimum of steps. The Master Troubleshooting Chart can be used without removing the cover from the Oscilloscope, and will indicate the circuit or circuits most likely to contain the casualty.

The individual circuit troubleshooting charts isolate probable casualty areas within the circuits themselves. The power supply voltages should always be checked before troubleshooting an individual circuit, to avoid false indications.

To use the charts, start at the top, working down and to the right. If a check provides a "yes" answer, proceed down along the solid line. If the check provides a "no" answer, proceed to the right, following the broken line. Exceptions to the direction of flow are indicated by arrows where they occur.

Rectangles contain the checks to be performed; the hexagons indicate the probable casualty area. When checking the probable casualty area, associated leads, switches and other components should not be ignored. A transistor might be inoperative because of a resistor in series with it.

The charts are designed on the basis of single casualties. Multiple casualties may disrupt the logic, but it should still be effective in determining the casualties, one at a time.

CORRECTIVE MAINTENANCE

General

Many electrical components are mounted in a particular way to reduce or control stray capacitance and inductance. Part orientation and lead dress should duplicate the original installation.

WARNING

Disconnect the Oscilloscope from power sources and remove the Power Pack before removing or replacing components. If the Power Pack is being worked on, unsolder and tape up one of the leads which connect the battery to terminals M and I of the Power Pack circuit board.

A thorough cleaning should accompany any repairs, and a satisfactory Performance Check or a Calibration Procedure should be performed after the repairs have been completed.

Parts Procurement

All parts used in this oscilloscope can be purchased through Tektronix Field Offices or representatives. However, replacements for standard electronic items can readily be obtained from local electronic parts stores.

When selecting replacement parts, it is important to remember that the physical size and shape of a component may affect its performance at high frequencies. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance. Before purchasing, consult the Electrical Parts List in Section 7 to determine the required specifications.

Special Parts. Some electrical parts are specially reworked, quality checked, or manufactured to fullfill a specific requirement. Most mechanical parts are common to the Type 323 Oscilloscope. All electrical parts whose stock numbers are preceded by an asterisk in Section 7, and most mechanical parts, can therefore be obtained only through the Type 323 Oscilloscope sales facilities. Ordering information precedes the Electrical Parts List in Section 7.

Soldering Equipment and Techniques

Soldering Equipment. Ordinary electrical solder should be used for all circuit repairs. The soldering iron should be selected in accordance with the work being done, as follows:

Soldering on circuit boards - 15 to 40 watt iron with a $1/16$ or $1/8$ inch tip.

Soldering to metal terminals such as on switches and potentiometers - 40 to 75 watt iron with $1/8$ inch tip.

Soldering to heavy metal such as the chassis or binding posts - 40 to 75 watt iron with $1/4$ inch tip.

Component size and density demands the use of needle-nose pliers and needle-nose end nipper pliers when replacing components. Tweezers are also helpful. Heat sinks (such as small alligator clips) are invaluable for protecting components from heat damage, leaving both hands free for soldering. A hold-down aid can be made from a wooden dowel, 6 to 8 inches long and $1/4$ to $3/8$ inch in diameter. Shape one end like a pencil tip and the other end similar to a screwdriver tip. Note that the wood will absorb only a minimum of heat from the iron, but also note that it will not guard against heat transfer to the parts being soldered. Flux remover solvent and cotton-tipped swabs are needed to remove flux from soldered connections.

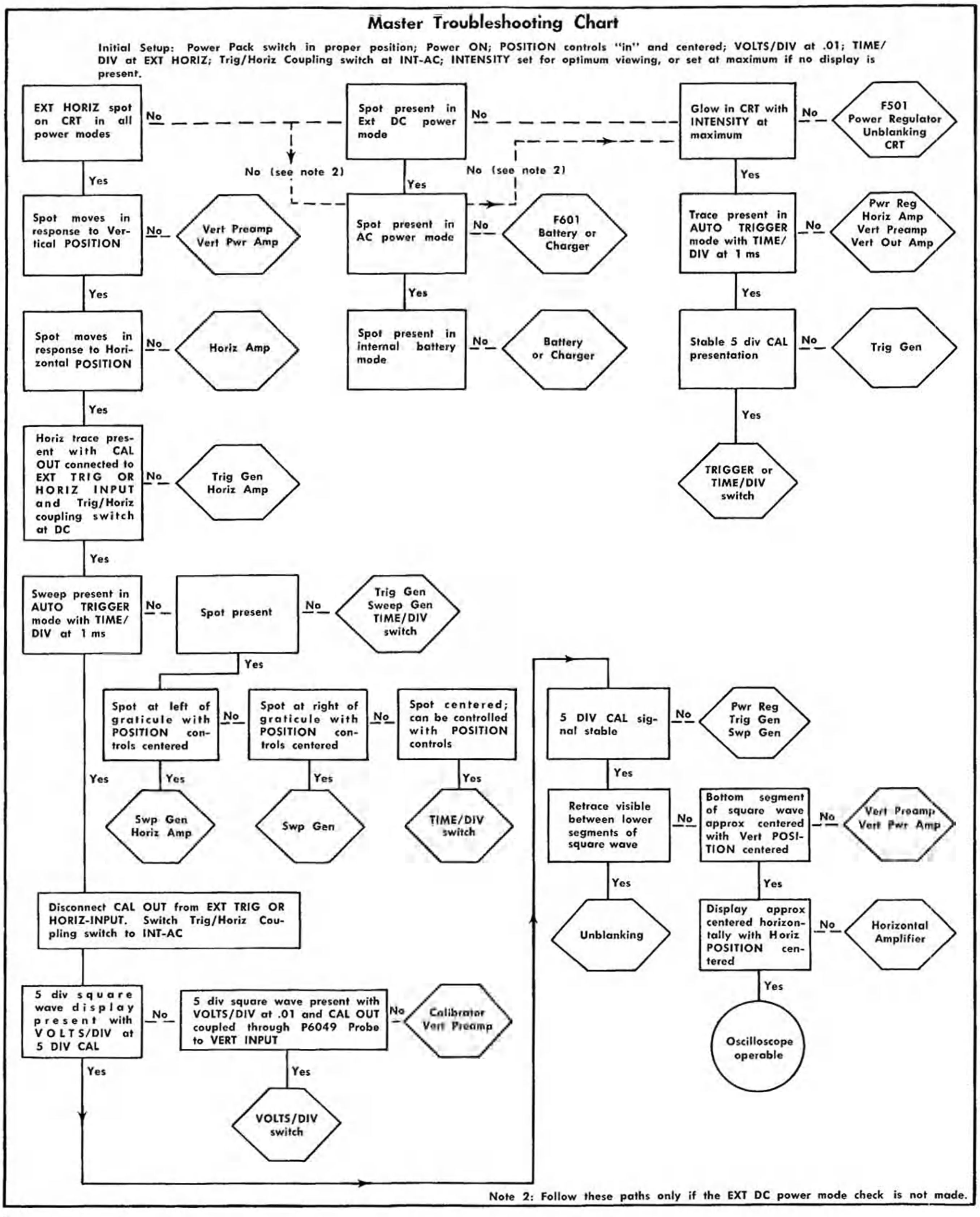


Fig. 4-3. Master troubleshooting chart.

POWER REGULATOR TROUBLESHOOTING CHART

Initial setup: VOLTS/DIV at 5 DIV CAL; POSITION controls "in" and centered; TRIGGER at + AUTO; TIME/DIV at 1 mS; Trig/Horiz Coupling switch at INT—AC; 115 V, 60 Hz AC power applied; POWER—ON; INTENSITY control at maximuum brightness setting.

The following observations were made with the indicated transistor removed from the circuit to simulate its being open. The chart need not be restricted to the transistors themselves, but can be used as a basis for tracing symptoms to areas of the Power Regulator circuit which are associated with indicated transistors. Circuit response may vary slightly between instruments.

Transistor Removed	Reaction of Power Supplies (Near normal unless indicated otherwise)			Comments
	High	Low	0 or near 0	
Q515			all	DC on Q525-C
Q518			all	DC on Q525-C
Q525			all	DC on Q525-C
Q529			all	40 V P-P pulses on Q525-C
Q555			+5, —5	Glow visible in CRT
Q557	+5, —5			Display visible; INTENSITY affects triggering and causes "blooming".
Q558			+5, —5	Glow visible in CRT
Q562	—5			Normal amplitude display visible; INTENSITY affects triggering and positioning; Top and bottom of square wave distorts when display is not centered vertically.
Q567	—5			
Q569		all	—5	All voltages (except —5) approximately 40% of normal value; 35 V P-P pulses on Q525-C.

Fig. 4-4. Power Regulator troubleshooting chart.

A solder removing device such as an EDSYN SOLDAPULLT, Tektronix Part No. 003-0428-00, is extremely useful in removing solder from circuit boards, expediting component removal and replacement.

Other soldering aids should be made or purchased to suit specific needs.

General Soldering Techniques. Keep the soldering iron well tinned and wiped clean. To avoid excessive heating of the general area around the connection, the iron should be completely heated before being applied. When removing components, apply heat only long enough to allow the part to be removed easily. (Applying a small amount of solder between the tip and the joint will usually aid in heat transfer on difficult connections. This will decrease heating of the general area.) Use the extreme tip of needle-nosed pliers to avoid drawing off too much heat. When connecting components, heat the solder sufficiently to allow free flow. Apply the solder to the wire being joined, not to the soldering iron. This will insure proper bonding. (Applying a small amount of solder between the iron and the wire will again aid in initial heat transfer. Once solder flows between the tip and the wire, the solder should be applied to the opposite side of the wire to complete the process.) Do not use more solder than is necessary to make a neat and effective bond.

Use heat sinks between the body of components and the joint being soldered whenever small components and/or short leads are involved. After soldering has been completed, clip off excess wire, deflecting wire ends with a gloved finger or other device to avoid damage to fingers, eyes, or circuit components. Remove clipped leads from the chassis. Clean the newly soldered area with a cotton-tipped swab and flux remover solvent.

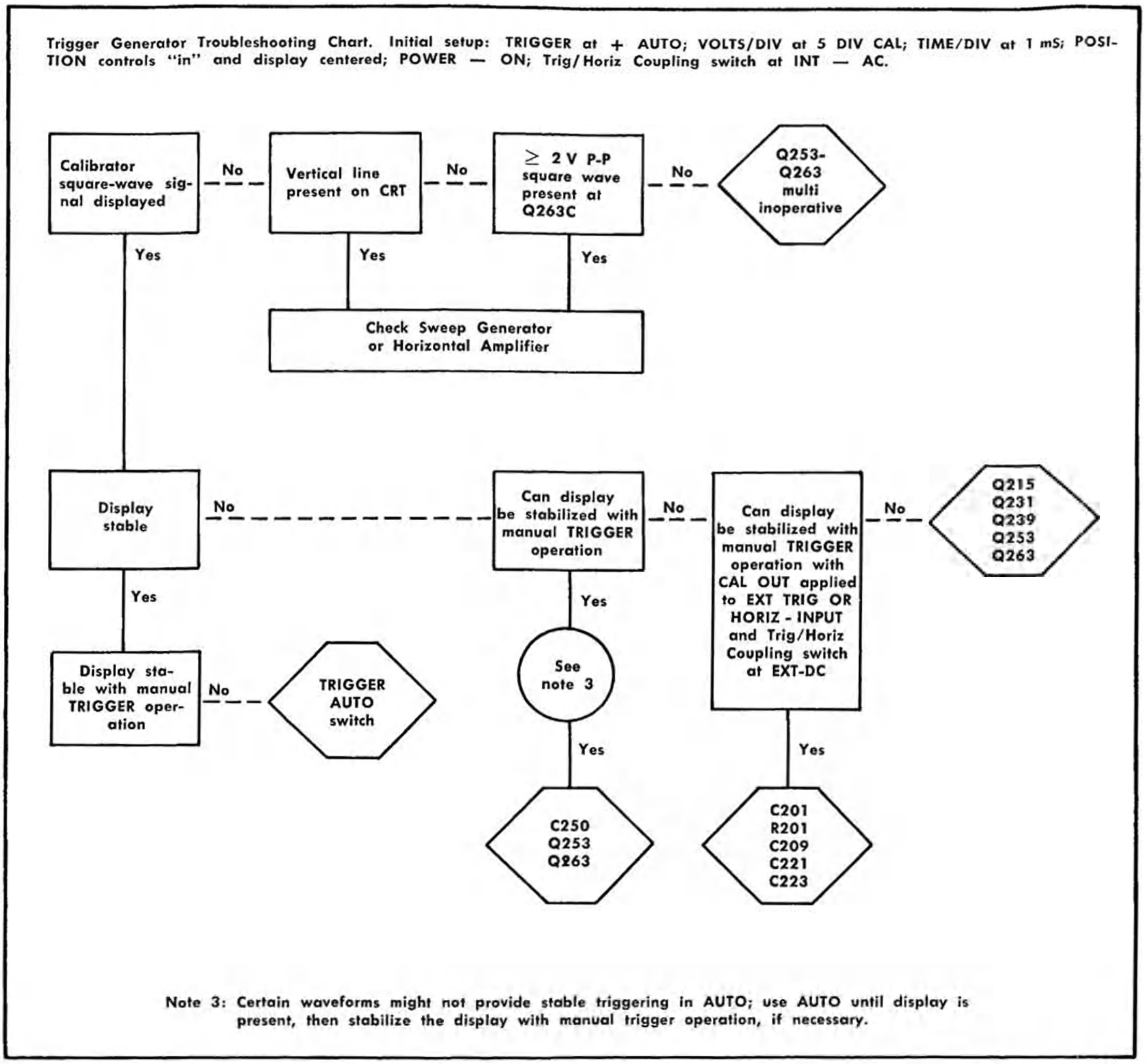


Fig. 4-5. Trigger Generator troubleshooting chart.

CAUTION

Use extreme care when soldering wafer-type switch terminals. Excessive heat or solder flowing around and beyond the rivet will destroy the contact's springs tension. Excessive heat will damage plastic switches.

Circuit Board Soldering Techniques. Use a 15 to 40 watt iron with a 1/8 inch tip. Keep the tip well tinned and clean. Do not overheat components or circuit board. Do not put excessive pressure on the board.

To remove a component, grip a lead with the tip of a pair of needle-nosed pliers. Touch the tip of the soldering iron to the connection. When the solder melts, gently pull the lead from the board. If a clean hole is not left in the board, reheat it and remove the solder with a solder removing device, or bore it out gently with a tooth-pick or similar non-abrasive device.

Defective multiple-lead components that cannot be removed by the above process should first be removed by cutting the leads. Then remove the leads one at a time and clean the holes as necessary. If the leads are not accessible, remove the solder from each contact point with a solder removing device, then work the component out, applying heat alternately to the connections involved.

Sweep Generator Troubleshooting Chart. Initial setup: Display is obtainable in EXT HORIZ mode; VOLTS/DIV set at 5 DIV CAL; TIME/DIV at .5 mS; POSITION controls "in" and centered; POWER — ON; VARIABLE controls at CAL; TRIGGER at + AUTO; Trig/Horiz Coupling switch at INT — AC.

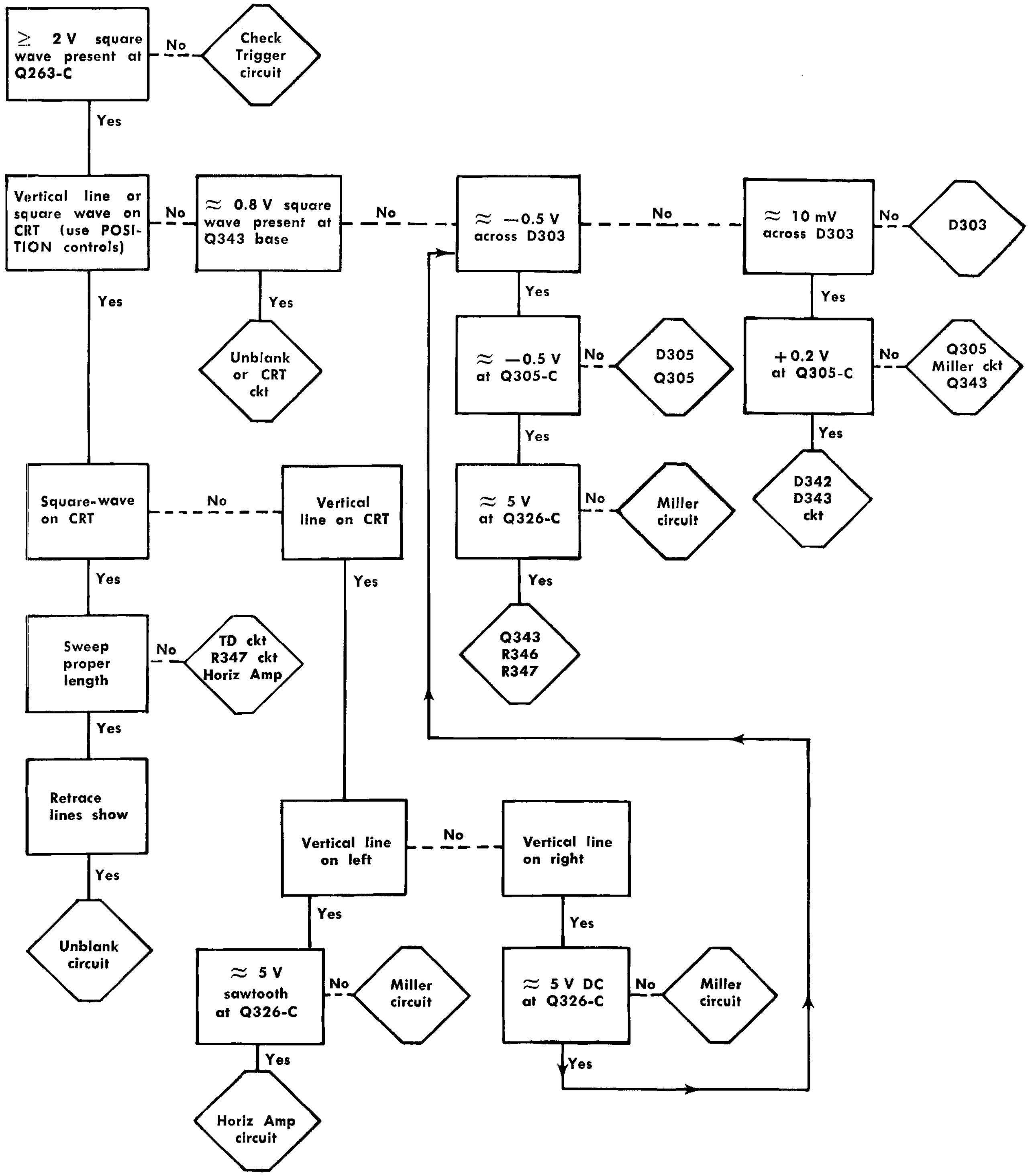


Fig. 4-6. Sweep Generator troubleshooting chart.

Horizontal Amplifier Troubleshooting Chart. Initial setup: VOLTS/DIV at 5 DIV CAL; POSITION controls "in" and centered; TIME/DIV at 1 mS; TRIGGER at + AUTO; Trig/Horiz Coupling switch at INT-AC; POWER — ON.

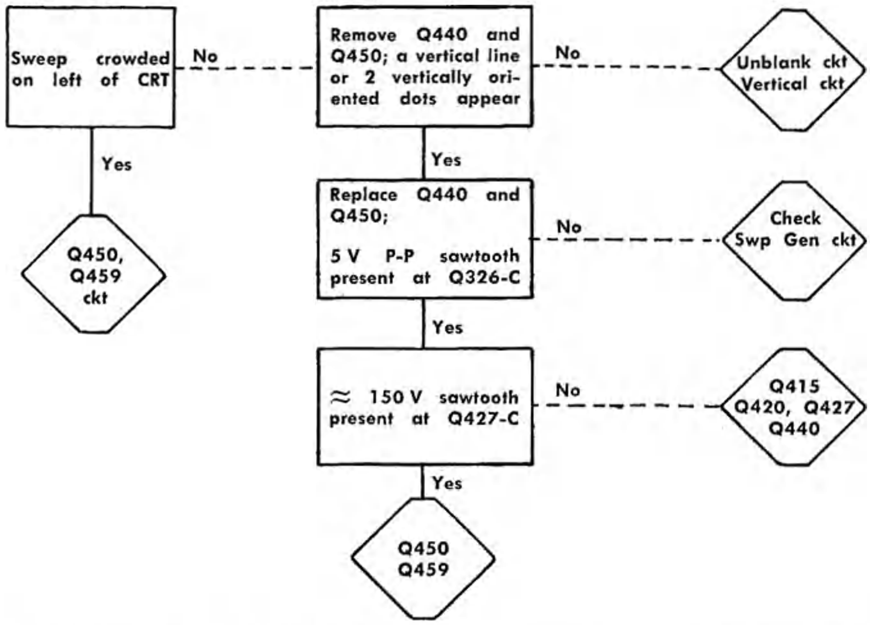


Fig. 4-7. Horizontal Amplifier troubleshooting chart.

Vertical Preamplifier and Output Amplifier Troubleshooting Chart. Initial setup: VOLTS/DIV at 5 DIV CAL; POSITION controls "in" and centered; TIME/DIV at 1 mS; TRIGGER at + AUTO, Trig/Horiz Coupling switch at INT — AC; POWER — ON.

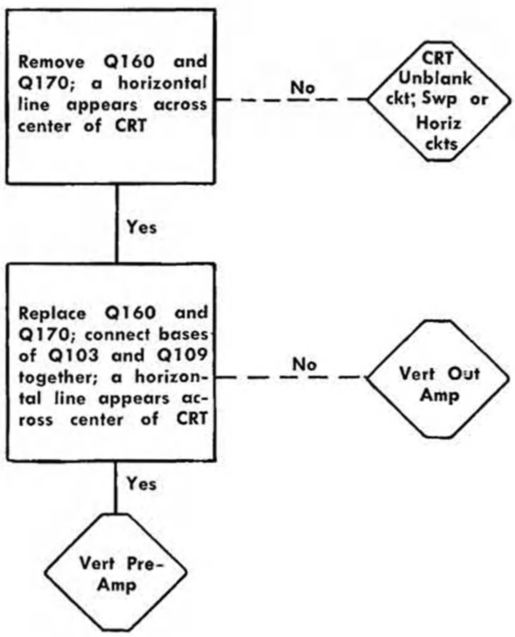


Fig. 4-8. Vertical circuit troubleshooting chart.

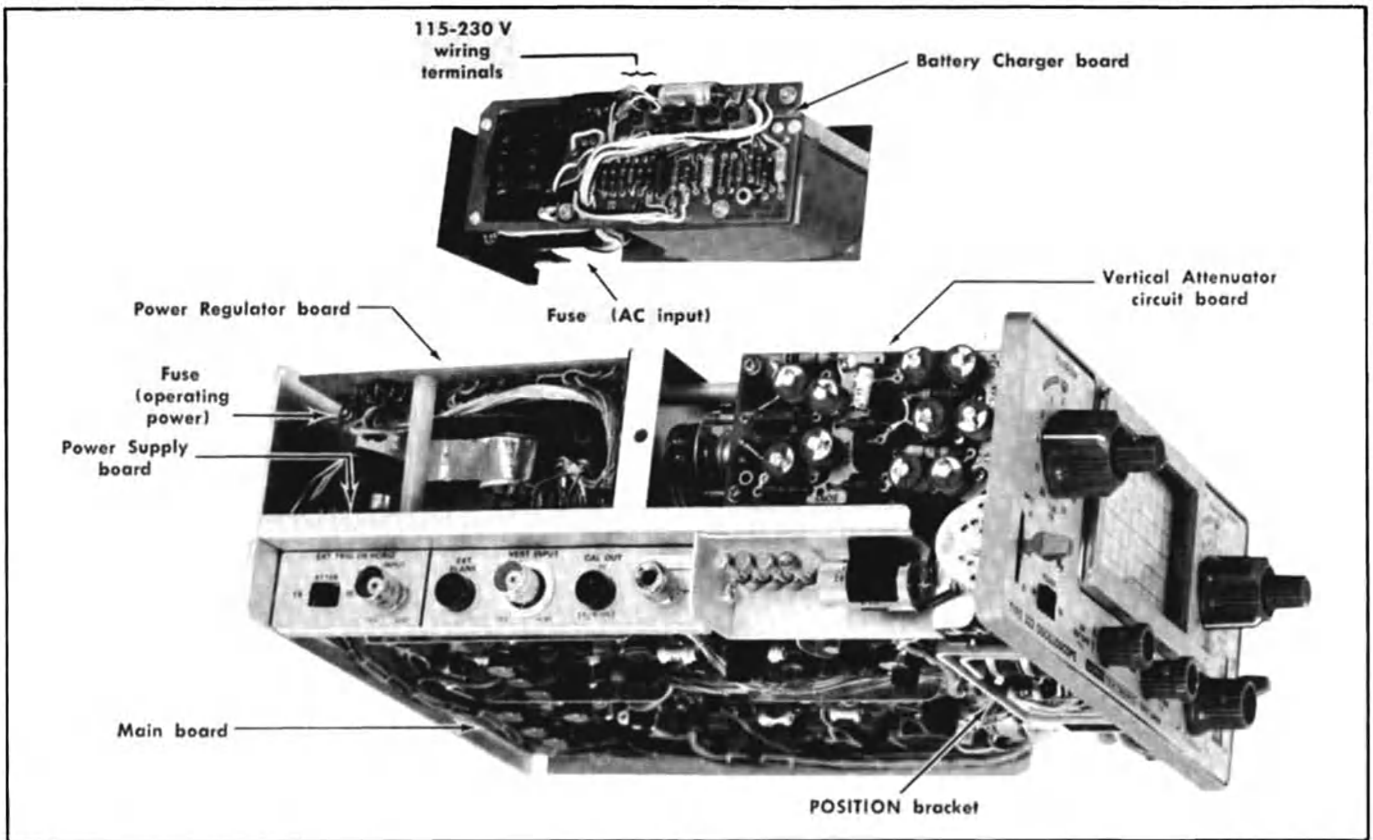


Fig. 4-9. Location view; bottom of Oscilloscope and Power Pack.

To replace components, first bend the leads to the proper shape. Cut the leads to proper size if the extra lead length interferes with installation or cannot be reached for cutting after installation. Insert the leads in holes and set the component to the position of the original part. Reheat holes if necessary for proper insertion of the part. Apply heat sinks to component leads as necessary. The tips of needle-nosed pliers serve as excellent heat sinks if only the component being installed needs protection. Apply the iron and a small amount of solder to the connection. Do not remove the iron until the solder flows freely. After removing the iron, hold the component steady until the solder is firm. Clip any excess lead wire. Clean the soldered area with a cotton-tipped swab and flux remover.

CAUTION

Ink used for circuit-board lettering will dissolve when contacted by certain types of solvents.

DISASSEMBLY AND ASSEMBLY

General

These instructions outline the most expeditious methods for removing components, or for exposing their surfaces so that they may be inspected or worked on. Undue force should not be used during disassembly or assembly. Soldering should be done in accordance with the information given earlier in this section under Soldering Instructions. Instructions for removing the Oscilloscope case and replacing the Power Pack are contained in the Operating Instructions and are not repeated here. The locations of specific parts of the Oscilloscope are shown in Fig. 4-9. Transistor installation information is contained in Fig. 4-13. The circuit boards are shown in Fig. 4-14 through 4-21, and indicate component locations and wire connecting points.

Power Pack

General. The Power Pack can be removed from the Oscilloscope by disconnecting three square-pin connectors at the circuit board, and releasing a toggle clamp at the front of the Power Pack. It is recommended that the Power Pack switch (at the rear of the Power Pack) be kept in the EXT DC position during removal and while the Power Pack is out of the Oscilloscope. This minimizes the number of points to which the internal battery is connected.

WARNING

The battery used in the Power Pack is capable of delivering a large amount of energy in a short time. Rings, watch bands, or other metallic items which short-circuit the battery can rapidly become hot enough to cause severe burns.

Circuit Board. Components on the Battery Charger circuit board can be replaced without removing the board. To reach the under-side of the board, remove the three nuts which hold the board in place. Turn the Power Pack over to permit the washers to fall free of the board.

CAUTION

Do not allow components to become short circuited while the battery pack is connected to the circuitry. If a resistance check or disassembly is to be performed, it is recommended that the battery lead connected to terminal M of the circuit board be unsoldered and taped to avoid damage.

After the nuts and washers have been removed, the outer end of the board can be lifted up, pivoting it on the wiring cable. Be careful that the screw near the transformer does not bind on the corner of the board. If the board must be completely removed, the wire color code should be recorded before any wires are unsoldered.

Transformer. To remove the transformer, unsolder its eight leads from the circuit board. Remove the Power Pack cover plate from the opposite side by removing the six screws from it. Then remove the two transformer mounting bolts; the transformer can then be lifted out through the hole in the side plate. See Fig. 4-10 for 115-230 V wiring information.

Fuse. Access to the fuse can be obtained by pulling the plastic cap off toward the bottom. When replacing it, be sure that the grooves in the cap align with the fuse mounting board. See Fig. 4-10 for 115-230 V fusing information.

Battery. The battery in the Power Pack is made up of six 1.25 V Nickel-Cadmium (NiCd) cells strapped together, series-aiding. See Fig. 4-11. Background information regarding these cells is given in the Operating Instructions section and should be read before any servicing is performed on the battery.

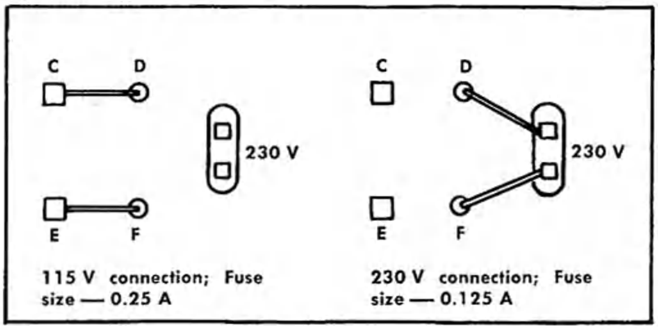


Fig. 4-10. Connections for 115 V and 230 V AC operation. Place insulated sleeves on unused square pins after changing the connections.

Battery Pack Removal. Unsolder the two leads which connect the battery pack to terminals I and M on the circuit board. Free the one lead from the cable clamp. Tape up one lead end (creating minimum bulk) so that the two leads cannot come in contact with each other. Remove the nine screws and the cover plate from the power connector side of the Power Pack. Remove the three battery pack screws through the access holes in the circuit board, freeing the pack. Separate the pack from the rest of the unit, pulling the pack leads through the hole in the circuit board. The battery holding bracket now can be removed by removing one screw from each end. The pack can be re-installed by reversing the procedure.

Servicing the Battery. The cells which make up the battery have been selected to meet specific performance requirements and can be expected to maintain relatively equal capabilities throughout the battery operating life. Upsetting this balance of equality by introducing a strong cell into a weak battery, or a weak cell into a strong battery, will precipitate reverse charging of the weakest cells, as explained in the Operating Instructions.

If one cell is defective and fails while the rest of the battery is still quite new, that cell may be replaced without undue concern. The Tektronix Field Representative or Office should be consulted before individual cells are replaced, especially if the warranty is in effect.

Gas evolution and recombination takes place during battery charging. This creates a pressure within the cells which they normally can withstand. If a cell becomes defective, or a circuit failure causes the recommended charge rate to be exceeded, excessive pressure builds up. The pressure may rupture a relief vent, exhausting the gas. This action may shorten the life of the cell, and will coat the surrounding areas with a corrosive substance.

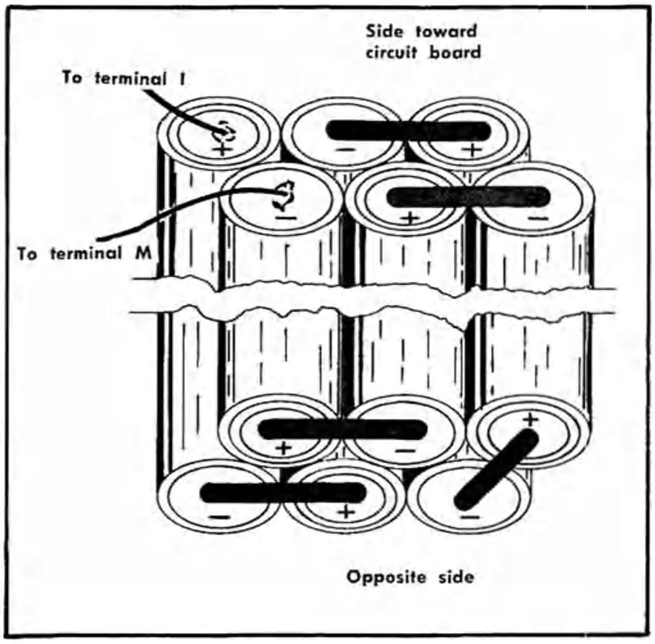


Fig. 4-11. Battery wiring.

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The battery should be inspected every six months or every 500 operating hours, whichever occurs first. Individual cells or the entire battery should be replaced if venting or excessive corrosion has occurred. The cover plate on the power connector side must be removed to expose one side of the battery. Sight between the cells to check for obvious corrosion or venting on the circuit board side. If a more thorough check of the circuit board side is desired, remove the battery in accordance with the Battery Pack Removal instructions.

Individual Cell Replacement. When necessary, individual cells can be removed and replaced by cutting the straps which connect the two ends of the cell to the pack, and soldering in a new cell. See Fig. 4-11. The cell type specified in the parts list must be used. Other types may not function properly, despite operating claims. They may prove to be a hazard to the instrument and to personnel. Operating time and/or temperatuure performance may be degraded. If, in an emergency, a substitute must be made, the cell must be able to withstand a 180 mA charge rate. The cells should then only be used as long as is necessary to obtain the prescribed replacements. The battery should be charged for 24 hours at a FULL CHG rate after individual cells are replaced.

Cathode Ray Tube (CRT) and Trace Rotation Coil

WARNING

High-vacuum cathode ray tubes are dangerous to handle. To prevent personal injury from flying glass in case of tube breakage, wear a face mask or safety goggles, and gloves.

Handle the CRT with extreme care. Do not strike or scratch it. Never subject it to more than moderate force or pressure when removing or installing.

Always store spare CRT's in original protective cartons. Save cartons to dispose of used CRT's.

After the Oscilloscope cover has been removed, the CRT and CRT shield can be removed through the following procedure:

Unscrew the black nylon thumb screw from directly behind the CRT. Then extract the black plastic spacer from between the CRT base and the chassis.

Remove the nut and bolt from the shield mounting bracket located near the rear of the shield.

Slide the CRT and shield back by pushing gently on the face of the CRT.

Raise up on the CRT and shield until the slack is taken up on the front and rear cables, and then remove the base socket from the CRT. Do not put too much strain on the cables while removing the base socket. Avoid bending the CRT base pins. The CRT is free to slide out of the front of the shield once the base socket is removed, so be careful not to drop it.

Slide the CRT out of the front of the shield. The trace rotation coil in the shield now is accessible. However, its two leads (which are soldered to terminals N and P at the main circuit board) must be unsoldered before the coil or the shield can be removed from the assembly.

Replacement. Reverse the procedure to replace the CRT, observing the following precautions:

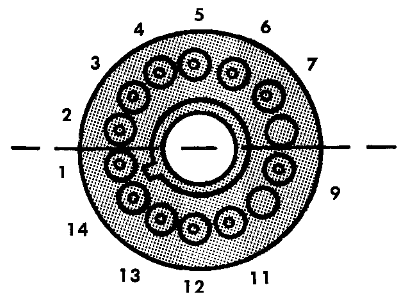

Fig. 4-12. Sketch of CRT base as viewed from rear when installed in oscilloscope.

The rotation coil must be installed with its narrower opening toward the rear of the shield.

CRT pin location and orientation in the Oscilloscope is shown in Fig. 4-12.

Do not strike the flanges (near the face of the CRT) against the shield when inserting the CRT in the shield.

When putting the CRT and shield in place, install the CRT shield inside the flanges on the right and left sides of the front panel CRT opening. The top of the shield must fit below the double flange at the top of the front casting. (The Oscilloscope case fits between the flanges.)

Replace the shield-bracket nut and bolt before the nylon screw, but do not tighten them until the plastic spacer and the nylon screw have been installed and tightened. The flanged side of the plastic spacer should face the front of the assembly, and the nylon screw must fit in the depression at the center of the spacer.) Use moderate torque to fasten the nylon screw, and then tighten the shield-bracket nut and bolt.

It is recommended that the Type 323 be recalibrated whenever a replacement CRT is installed.

Main Circuit Board

Most of the circuit components can be replaced without removing the circuit board. If access is required to the underside of the board, proceed as follows:

Record the color code and then unsolder the six wires which come from under the board at the rear panel, near the center.

Record the color code and then unsolder the two wires which come through the board near the side panel Ground binding post.

Remove one screw from each end of the side control panel, and remove the nut which is located near the inside-center of the panel.

Remove the five screws which hold the board to the chassis.

Lift the board and side panel away from the chassis, hinging it on the cable harness at the front of the board.

Position Bracket

Remove both POSITION knobs. Remove one securing nut and lock washer from each end of the POSITION bracket. Move the rear of the bracket away from the chassis, as far as the cables will allow. Then move the bracket back and out, hinging it on the cables at the rear of the bracket.

TRIGGER Control Assembly

Remove the TRIGGER knob; then remove the nut and flat washer from the exposed bushing. Lift the rear of the assembly away from the chassis and pull it back until the shaft clears the front panel. Note that the internal lock washer is in place between the TRIGGER assembly and the front panel during re-installation.

INPUT and Trig/Horiz Coupling Switches

These can be removed after two nuts have been removed from the back, and the pressure-fit knob has been pulled from the lever arm. To avoid damage to switch contacts, unsolder the coupling capacitor (C20) before removing the INPUT Coupling switch.

POWER Switch

The face plate must be removed from the Oscilloscope to expose the two machine screws holding this switch in place. The black-and-green plastic indicator plate should be removed and set aside until re-assembly.

Power Regulator Enclosure

Access to the enclosure can be had by removing two nuts and bolts from the front and one machine screw from the rear of the cover.

WARNING

More than 2000 V is present in the enclosure when the Oscilloscope is energized.

Fuse. The fuse (operating power) is located at the rear of the compartment on the component side of the Power Regulator board. It can be replaced without removing the board. The cause of a blown fuse should be investigated before replacing it. Only 1A- 250 V fast blow fuses should be used as replacements. A spare fuse is provided with the Oscilloscope and is contained in the spare-fuse holder located near the Attenuator circuit board.

Power Regulator Circuit Board. Access to the component side of this board and to the other circuitry in the compartment can be had by removing the three screws from the upper surface, and then lifting the board up and out, pivoting it on the wiring harness at the side of the board.

Power Supply Circuit Board. For access to the bottom of this board, perform the following:

Remove the Power Regulator circuit board. Then unscrew the three nylon mounting posts. Turn the Oscilloscope upside-down to permit two lock washers to fall free, and set them aside until re-assembly. During re-assembly, replace the two lock washers on the innermost machine screws. **Do not put a washer on the outer screw.**

Using the flat side of the tip of a screwdriver, push the three plastic collets (which encircles the cables) out of their mounting holes and up the cables. Apply moderate pressure to alternate points on the collets until they are worked out of the holes.

Raise up on the board, keeping it parallel to the chassis until it is clear of the mounting screws. Then raise up its outer edge to expose the under-side of the board.

Transformer and Toroids. Leads should be tagged, or a written record should be made of the connections whenever these components are removed. The windings can be recognized by the point at which they leave the assembly; the ends can be distinguished either by lead length or by color code. Do not untwist any of the paired leads.

VOLTS/DIV, TIME/DIV, FOCUS and INTENSITY Control Assemblies

The front casting must be loosened and swung down and forward in order to remove these controls. Proceed as follows:

Remove the CRT and shield, following the previously-given directions. Using a $1/16$ inch allen wrench, loosen two set screws in the VOLTS/DIV knob and two in the TIME/DIV knob. Loosen one set screw in each of the variable knobs and in the POSITION knobs and the TRIGGER knob. Pull all of the knobs (except for the POWER switch) off their shafts.

Remove the four machine screws which fasten to the chassis frame posts.

Remove the screw which holds the frame post and Power Pack toggle clamp to the chassis, and remove the frame post.

Open the Power Regulator Enclosure and remove the Power Regulator circuit board. Remove the machine screw from the frame post, moving the foil shield as necessary. Remove the frame post from the assembly.

The front casting can now be swung down and forward sufficiently to permit access to, or removal of, the controls under consideration.

LOW BATT Indicator

The indicator lamp is soldered to the base cap which is snapped in place over the indicator holder. To remove it, force the cap off the holder.

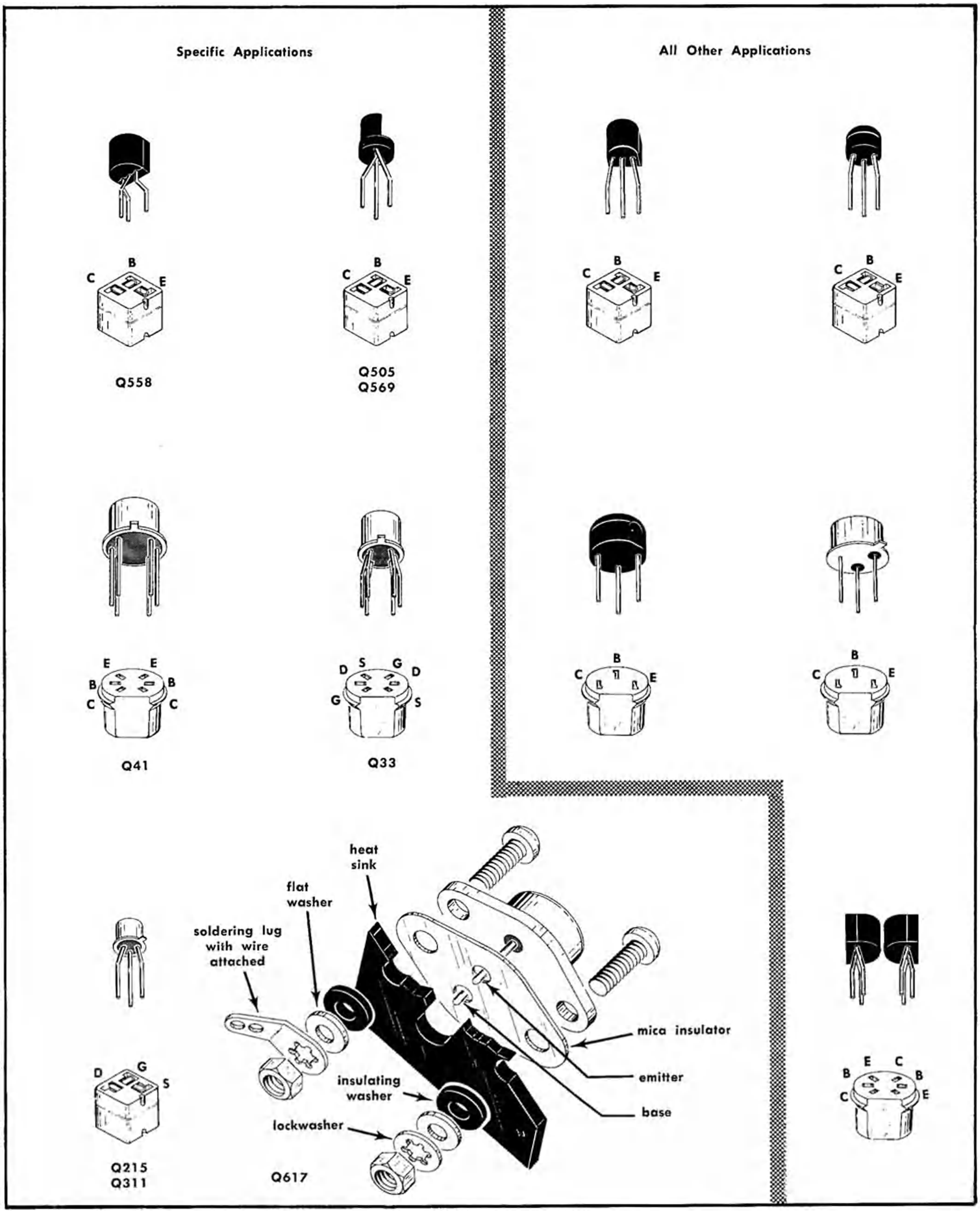

Fig. 4-13. Transistor data.

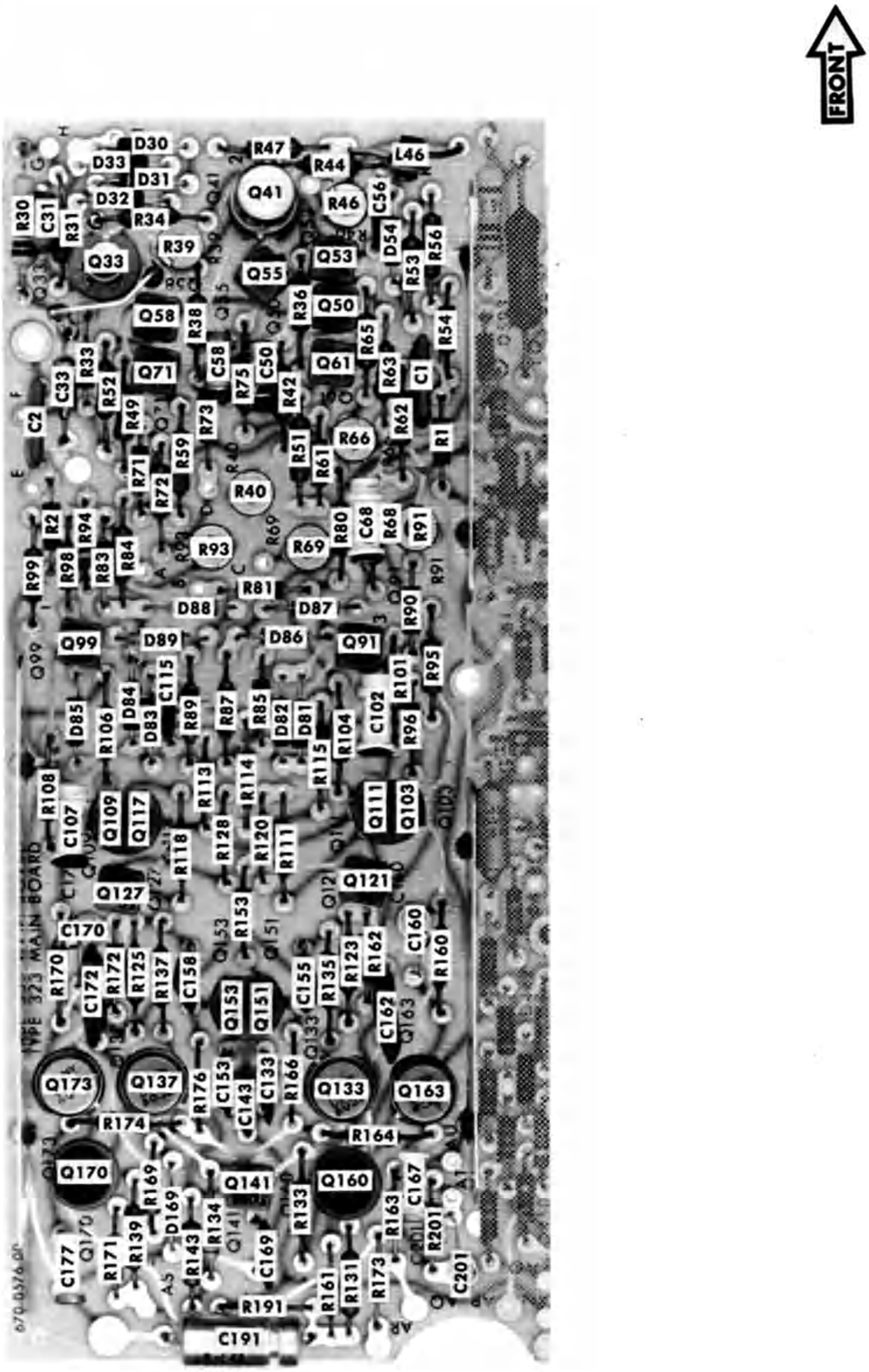

Fig. 4-14. Main circuit board (partial); left side—vertical circuit components.

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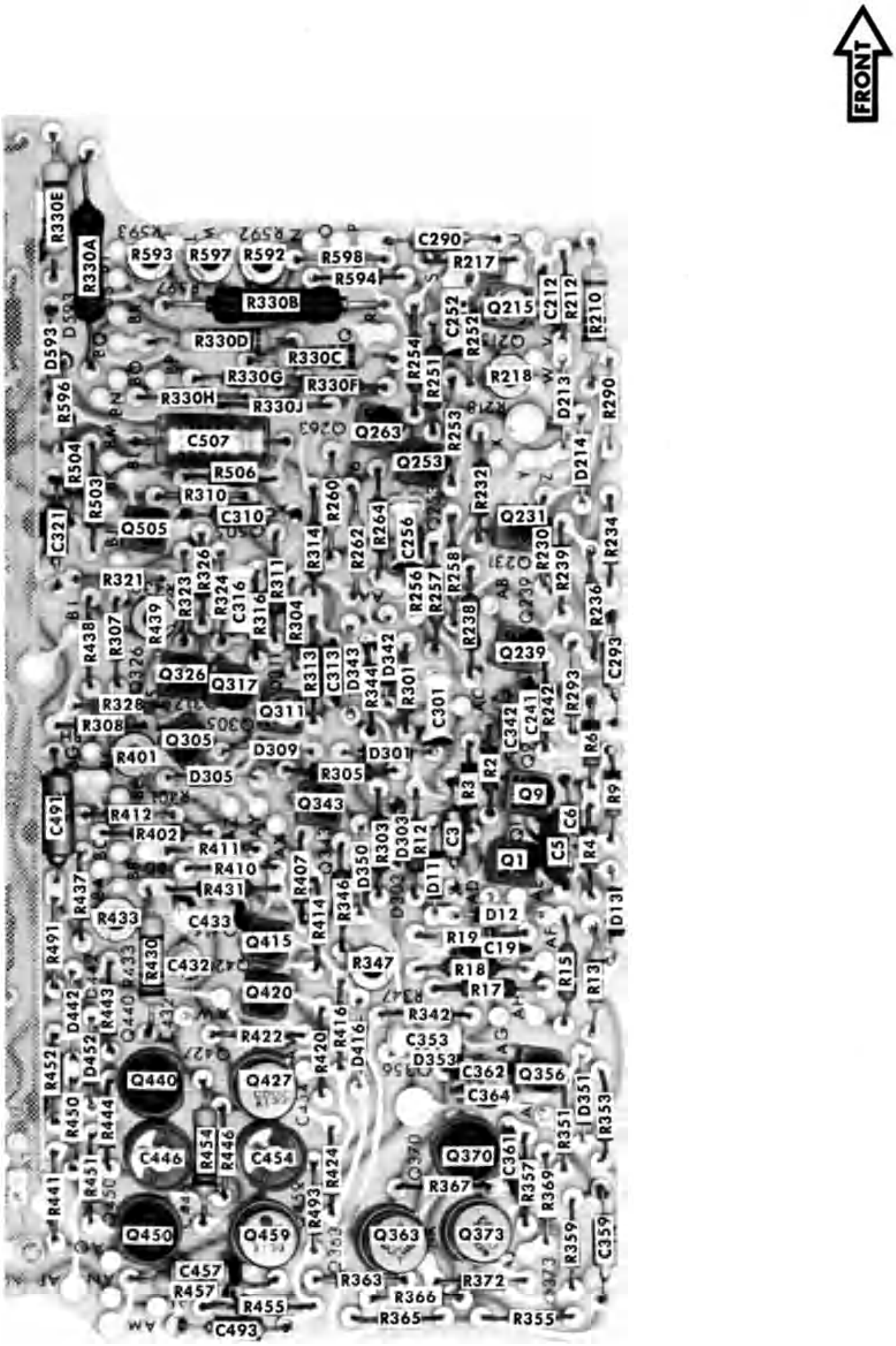

Fig. 4-15. Main circuit board (partial); right side—trigger and horizontal circuit components.

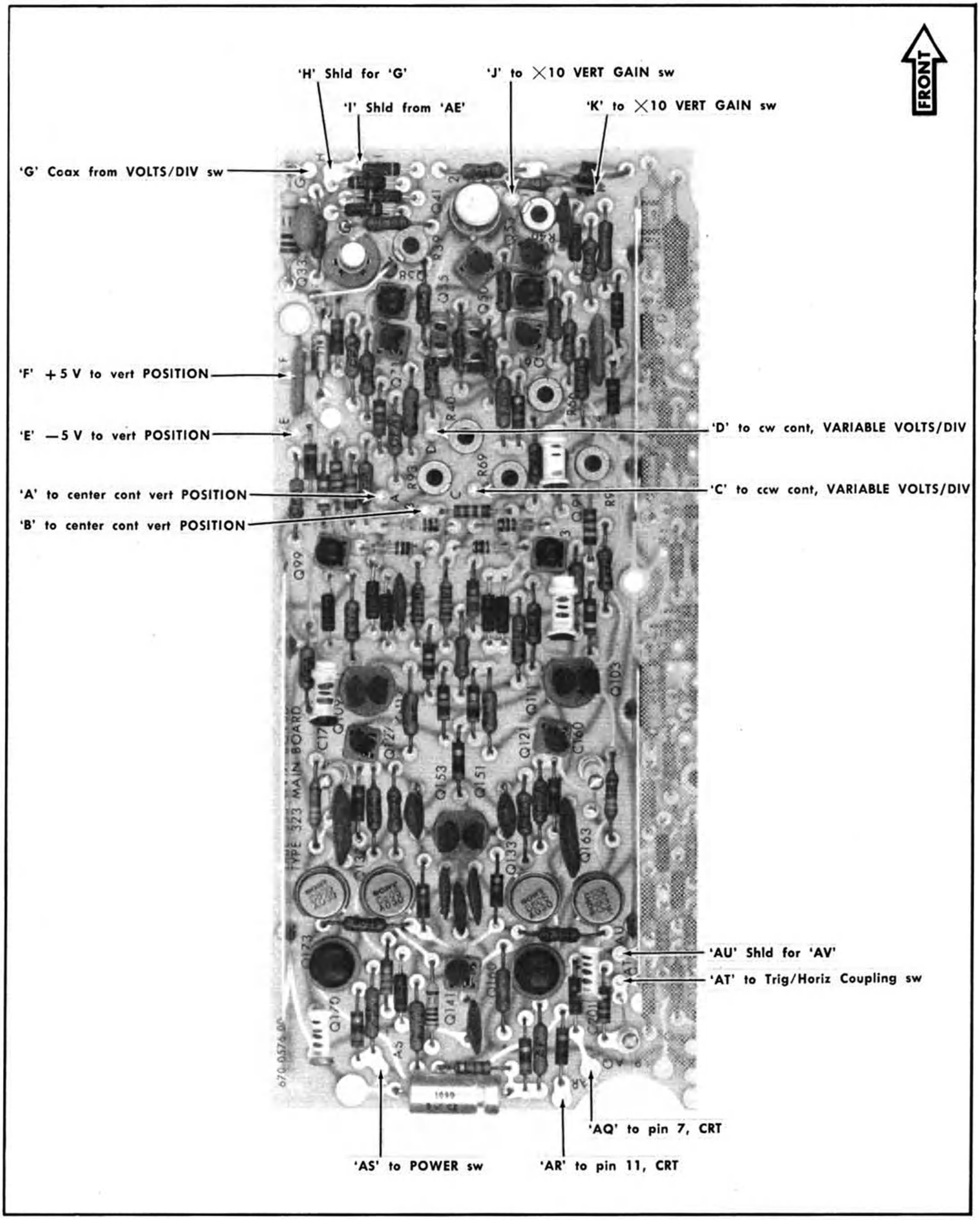

Fig. 4-16. Main circuit board (partial); left side—wire connections.

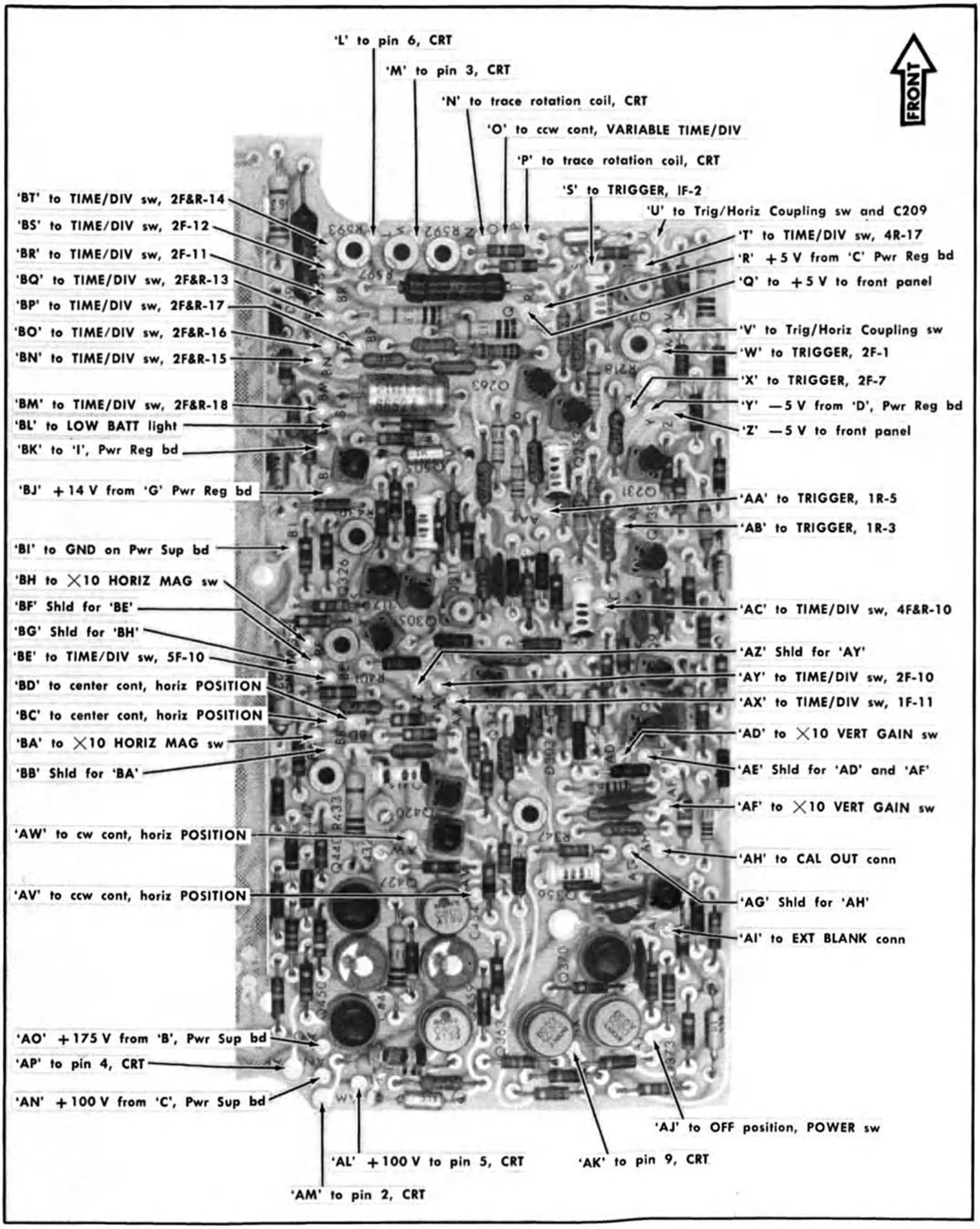

Fig. 4-17. Main circuit board (partial); right side—wire connections.

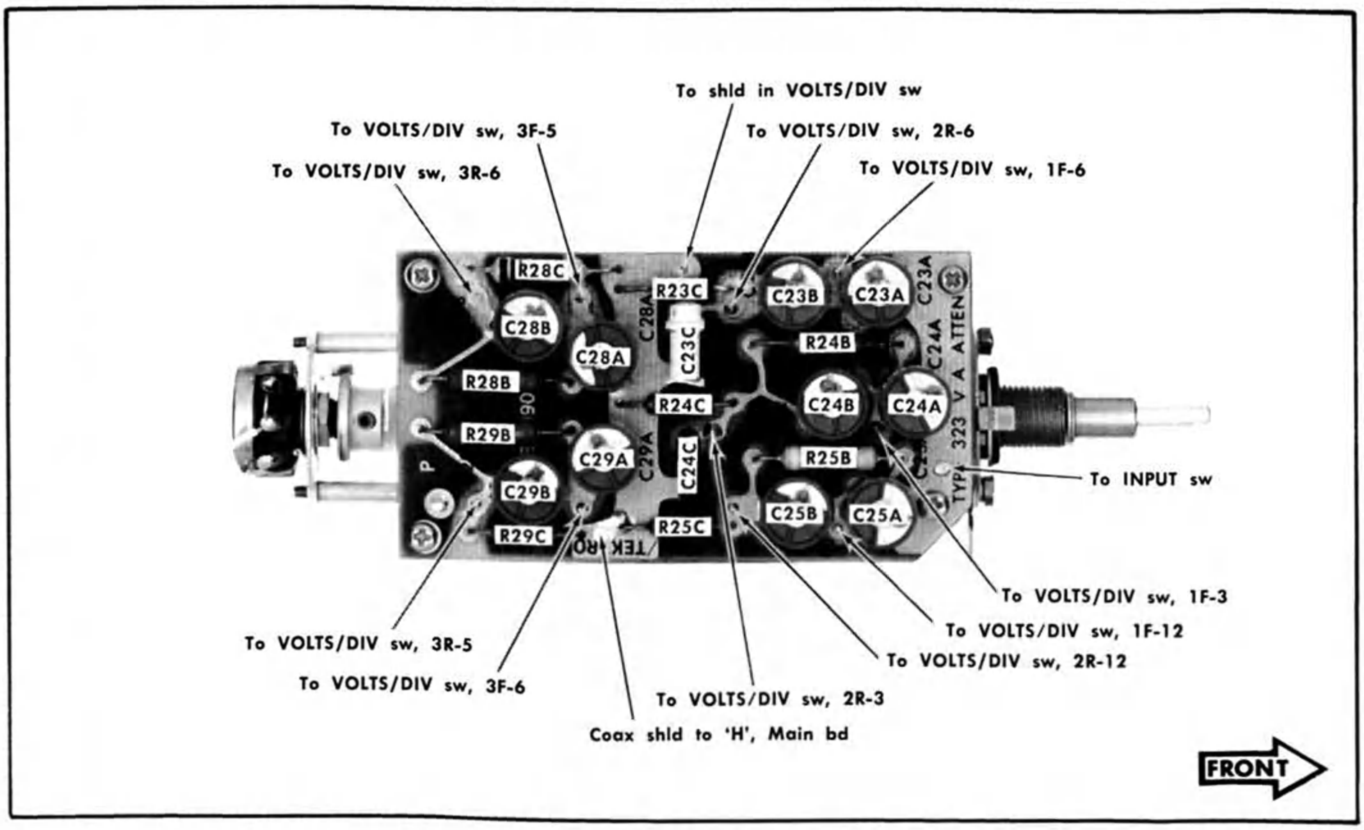

Fig. 4-18. Vertical Attenuator circuit board.

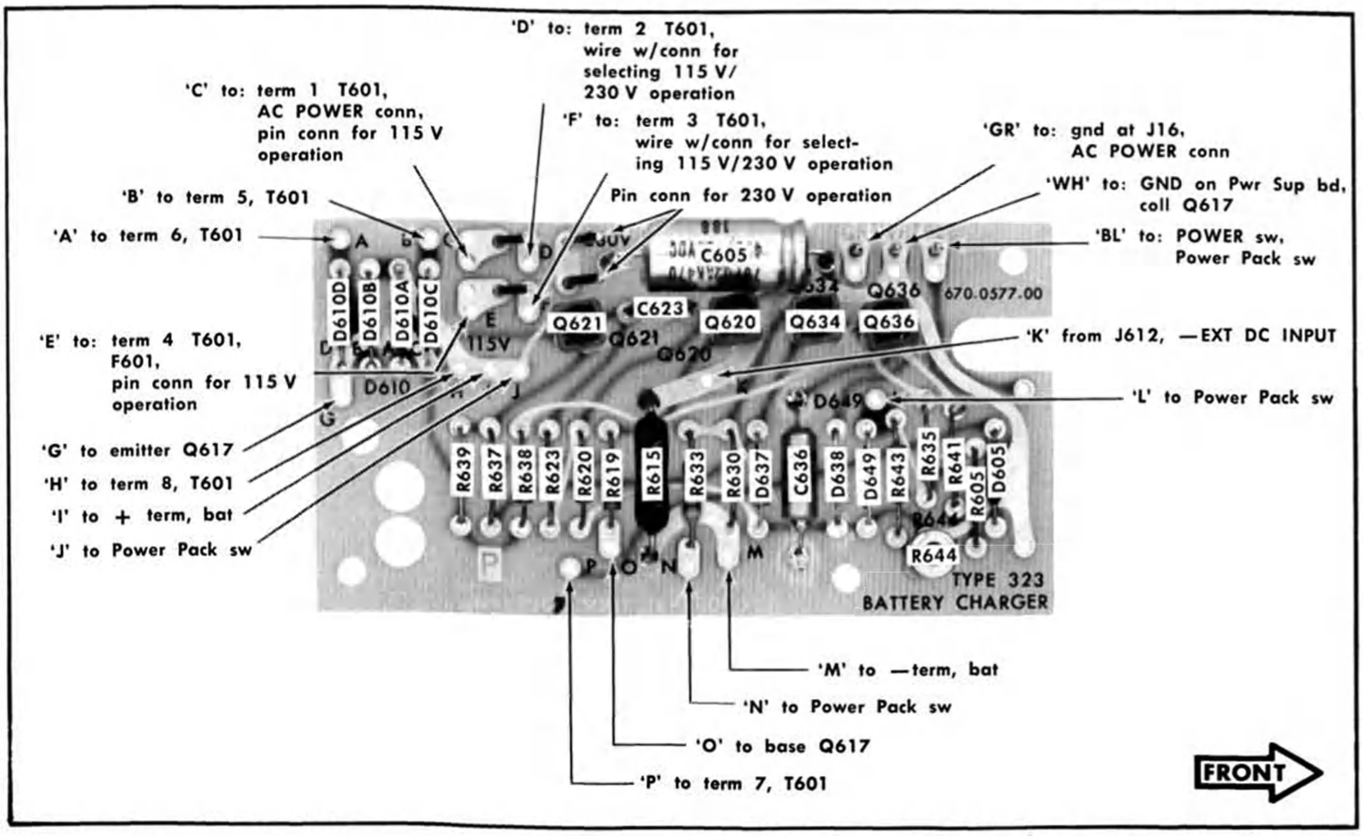

Fig. 4-19. Battery Charger circuit board.

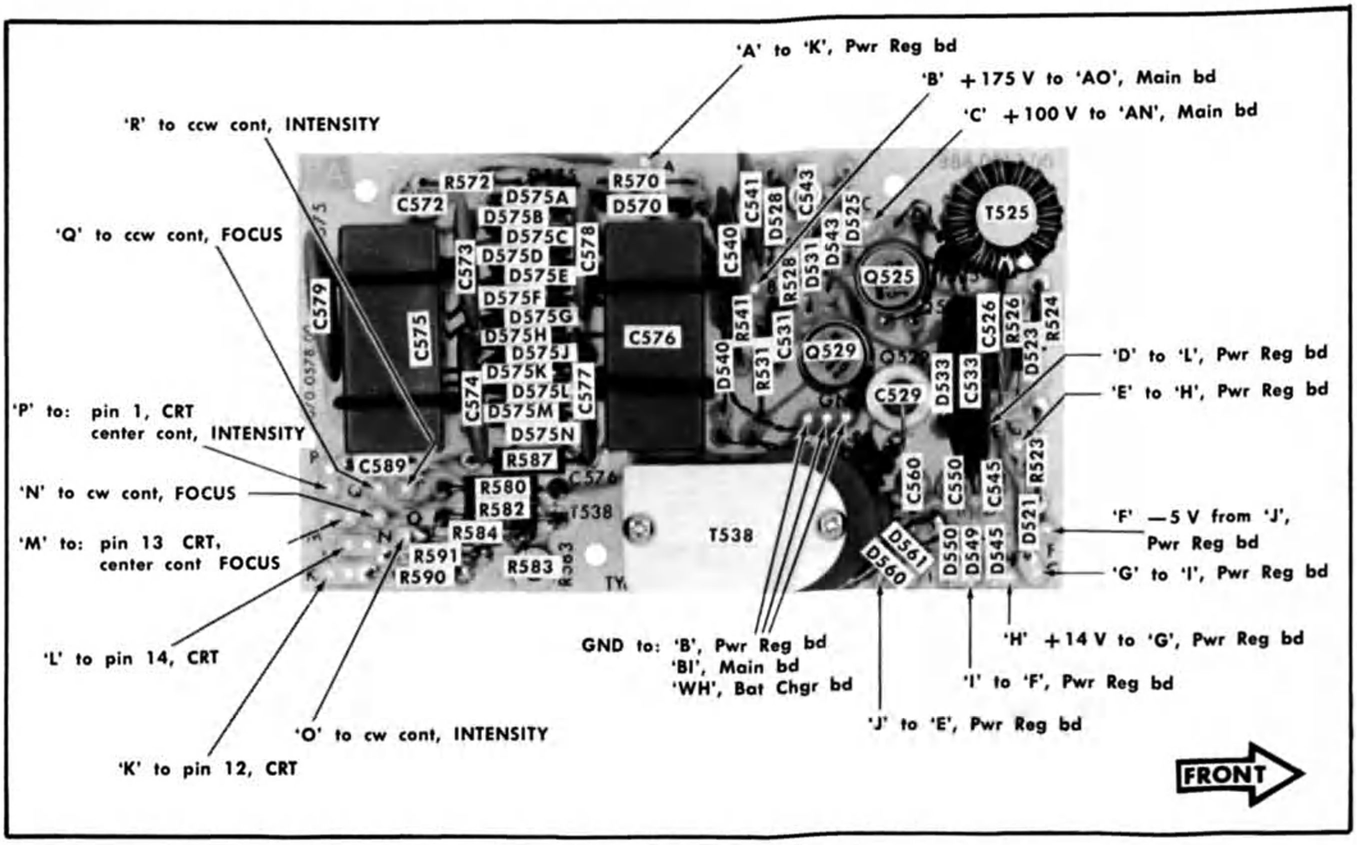

Fig. 4-20. Power Supply circuit board.

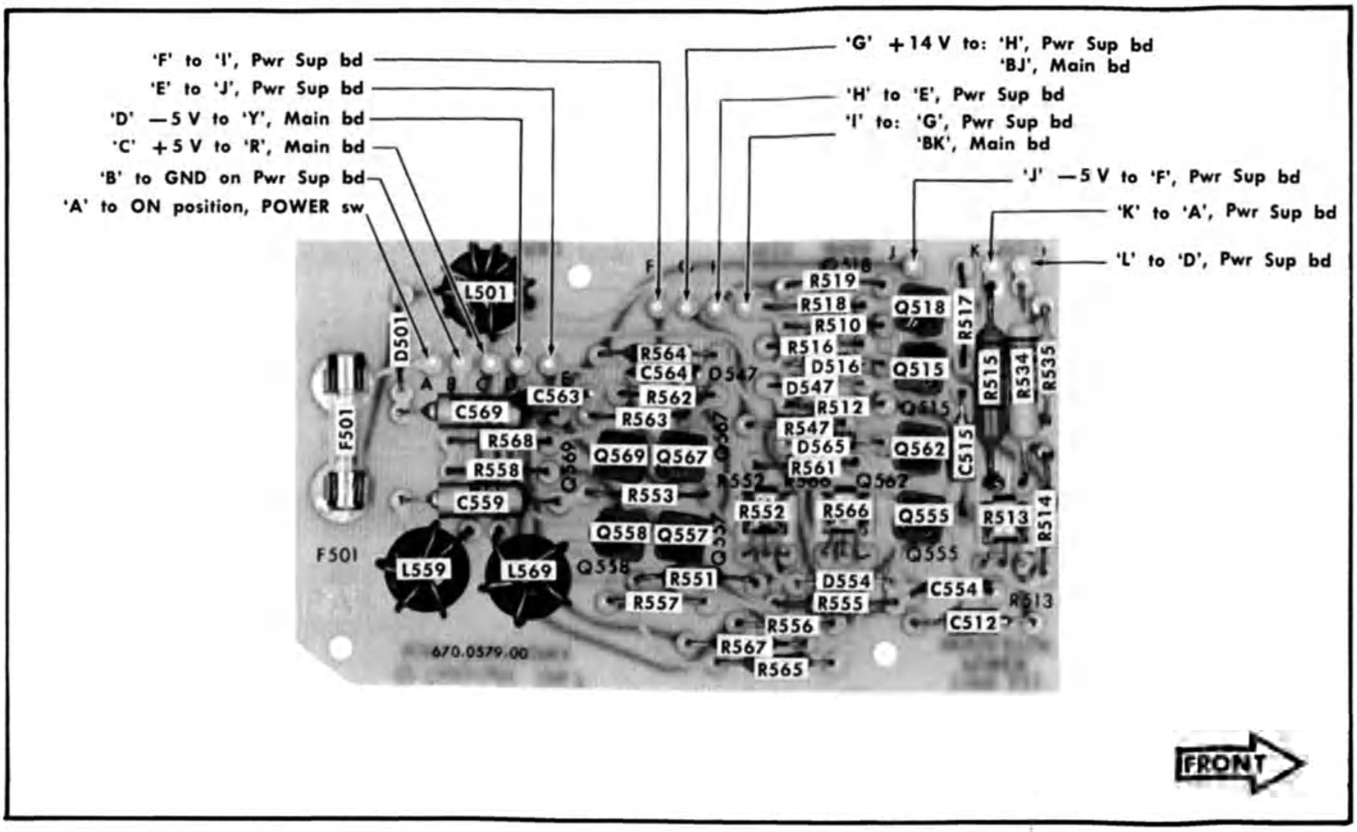

Fig. 4-21. Power Regulator circuit board.

SECTION 5
PERFORMANCE CHECK

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

This section of the manual provides a procedure for checking the performance of the Type 323. This procedure checks the operation of the instrument without removing the cabinet or making internal adjustments. However, the adjustment procedure is given for screwdriver adjustments which are accessible without removing the cabinet.

If the instrument does not meet the performance requirements given in this procedure, internal checks and/or adjustments are required. See the Calibration section of this manual. All performance requirements correspond to those given in Section 1 of this manual.

NOTE

All waveforms shown in this section are actual photographs taken directly from the graticule.

Recommended Test Equipment

The following test equipment and accessories are recommended for a complete performance check. Specifications given are the minimum necessary to perform this procedure. All equipment is assumed to be calibrated and operating within the given specifications. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

For the most accurate and convenient procedure, special Tektronix calibration fixtures are used in this procedure. These special calibration fixtures are available from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

1. Variable DC power supply.[1] Voltage range, +6 to +8 volts; current capability, 0.75 ampere; output voltage measured within 3%; must have meter to indicate output voltage.

2. Time-mark generator. Marker outputs, 0.5 microsecond to five seconds; marker accuracy, within 0.1%. Tektronix Type 184 Time-Mark Generator recommended.

3. Standard amplitude calibrator. Amplitude accuracy, within 0.25%; signal amplitude, five millivolts to 100 volts; output signal, square wave and positive DC; must have mixed display feature. Tektronix calibration fixture 067-0502-00 recommended.

4. Square-wave generator. Must have the following output capabilities (may be obtained from separate generators): 120 volts amplitude at one kilohertz repetition rate with a one microsecond risetime; 500 millivolts into 50 ohms at one kilohertz and one megahertz repetition rates with a 50 nanosecond risetime. Tektronix Type 106 Square-Wave Generator recommended (meets both output requirements).

5. High-frequency constant-amplitude sine-wave generator. Frequency, 350 kilohertz to above four megahertz, reference frequency, 50 kilohertz; output amplitude, variable from five millivolts to 0.5 volt into 50 ohms; amplitude accuracy, constant within 3% at 50 kilohertz and from 350 kilohertz to above four megahertz. Tektronix Type 191 Constant Amplitude Signal Generator recommended.

6. Low-frequency constant-amplitude sine-wave generator. Frequency, two hertz to 100 kilohertz; output amplitude, variable from 50 millivolts to 16 volts peak to peak; amplitude accuracy, constant within 3% from two hertz to 100 kilohertz. For example, General Radio 1310-A Oscillator (use a General Radio Type 274QBJ Adaptor to provide BNC output).

7. Cable (two). Impedance, 50 ohms; type, RG-58/U; length, 42 inches; connectors, BNC. Tektronix Part No. 012-0057-00.

8. Adapter. Adapts GR874 connector to BNC male connector. Tektronix Part No. 017-0063-00.

9. Termination. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0049-00.

10. 10× attenuator. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0059-00.

11. Input RC normalizer. Time constant, 1 megohm × 47 pF; attenuation, 2×; connectors, BNC. Tektronix calibration fixture 067-0541-00.

12. 10× probe for Type 323. Tektronix P6049 Probe recommened (supplied accessory).

13. BNC post jack. Tektronix Part No. 012-0092-00.

14. BNC T connector. Tektronix Part No. 103-0030-00.

15. Patch cord. Length, six inches; connectors, banana plug-jack and BNC male. Tektronix Part No. 012-0089-00 (supplied accessory).

16. Patch cord. Length, 18 inches; connectors, banana plug-jack and BNC male. Tektronix Part No. 012-0091-00.

17. Screwdirver. Three-inch shaft, 3/32-inch bit for slotted screws. Tektronix Part No. 003-0192-00.

PERFORMANCE CHECK PROCEDURE

General

In the following procedure, control settings or test equipment connections should be changed only as directed. If

[1]**May be deleted and instrument connected directly to applicable power source if step 1 is not performed.**

only a partial check is desired, refer to the preceding step(s) for setup information. External controls or adjustments of the Type 323 referred to in this procedure are capitalized (e.g., VOLTS/DIV).

The following procedure uses the equipment listed under Recommended Test Equipment. If equipment is substituted, control settings or setup may need to be altered to meet the requirements of the equipment used.

Preliminary Procedure

1. Connect the Type 323 to the variable DC power supply output (set for +8 volts) or directly to a power source (if step 1 is deleted) which meets the voltage and frequency requirements of this instrument.

NOTE

Battery operation can be used for this procedure if the internal batteries are fully charged before proceeding.

2. Set the Type 323 controls as follows:

Vertical Controls	
VOLTS/DIV	.01
VARIABLE	CAL
INPUT	GND
Vertical POSITION	Midrange
×10 VERT GAIN	Pushed in
Triggering Controls	
TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1×
Horizontal Controls	
TIME/DIV	1 ms
VARIABLE	CAL
Horizontal POSITION	Midrange
×10 HORIZ MAG	Pushed in
CRT Controls	
FOCUS	Adjust for focused display
INTENSITY	Adjust for visible display
Power Controls	
POWER	ON
Power Pack (rear panel)	As necessary for power source

3. Set the POWER switch to ON. Allow several minutes warm up before proceeding.

1. Check Low Batteries Indicator

REQUIREMENT—LOW BATT light begins to flash when applied DC voltage is reduced to +6.25 volts, ±0.31 volt.

a. Slowly decrease the output voltage of the variable DC power supply.

b. CHECK—LOW BATT light begins to flash when variable DC power supply output voltage is +6.25 volts, ±0.31 volt (if variable DC power supply does not have an accurate meter to indicate output voltage, use an accurate DC voltmeter to monitor the output for this step).

c. Return variable DC power supply output voltage to +8 volts.

2. Check Variable Volts/Division Balance

REQUIREMENT—Less than one division vertical trace shift as the VARIABLE VOLTS/DIV control is rotated throughout its range.

a. Position the trace to the center horizontal line with the vertical POSITION control.

b. CHECK—Rotate the VARIABLE VOLTS/DIV control throughout its range. Trace should not move more than one division vertically (if the trace is not visible at all, preadjust the VAR V/DIV BAL adjustment to bring the trace on screen).

c. If there is excessive trace shift, adjust the VAR V/DIV BAL adjustment (on bottom of instrument) for no trace shift as the VARIABLE VOLTS/DIV control is rotated. If necessary, use the vertical POSITION control to keep the trace on screen during this adjustment.

3. Check Vertical ×10 Balance

REQUIREMENT—Less than one division vertical trace shift as the ×10 VERT GAIN switch is pulled out.

a. Return the VARIABLE VOLTS/DIV control to CAL.

b. Position the trace to the center horizontal line with the vertical POSITION control.

c. Pull the ×10 VERT GAIN switch out. Be careful not to change knob position as the ×10 VERT GAIN switch is pulled out.

d. CHECK—Trace shift less than 1.5 divisions vertically.

e. If there is excessive trace shift, adjust the VERT ×10 BAL adjustment (on bottom) for minimum trace shift as the ×10 VERT GAIN switch is pulled out (if adjustment is made, recheck step 2).

4. Check Astigmatism

REQUIREMENT—Best definition of marker display.

a. Change the following control settings:

VOLTS/DIV	.5
INPUT	DC
×10 VERT GAIN	Pushed in

b. Set the INTENSITY control midway between a barely visible trace and fully clockwise.

c. Connect the time-mark generator (Type 184) to the VERT INPUT connector with the 42-inch BNC cable.

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d. Set the time-mark generator for one millisecond markers.

e. If necessary set the TRIGGER control for a stable display.

f. CHECK—Markers should be well defined within the areas indicated in Fig. 5-1 with optimum setting of focus control.

g. If necessary, adjust FOCUS control and ASTIG adjustment (on bottom) for the best definition of the markers within the areas indicated in Fig. 5-1.

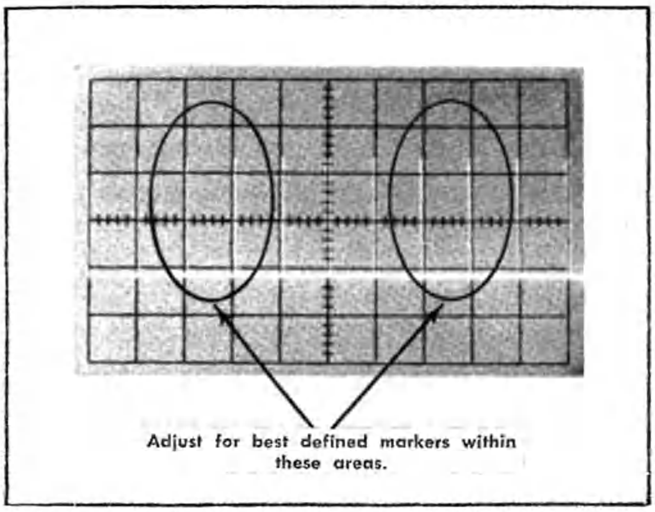


Fig. 5-1. Typical CRT display when checking astigmatism.

5. Check Trace Alignment

REQUIREMENT—Trace parallel to horizontal graticule lines.

a. Position the baseline of the marker display to the center horizontal line with the vertical POSITION control.

b. CHECK—Baseline of marker display should be parallel to the center horizontal line.

c. If necessary, adjust the TRACE ROTATION adjustment (on bottom) so the baseline of the marker display is parallel to the center horizontal line.

6. Check CRT Geometry

REQUIREMENT—0.1 division or less curvature of markers.

a. Set the VOLTS/DIV switch to .1.

b. Position the baseline of the marker display below the bottom of the graticule with the vertical POSITION control.

c. CHECK—CRT display for curvature of vertical lines (markers) within maximum deviation of 0.1 division from straight line. Fig. 5-2 shows a typical display of good geometry.

d. Disconnect the time-mark generator.

e. Position the trace to the top line of the graticule with the vertical POSITION control.

f. CHECK—Deviation from straight line should not exceed 0.1 division.

g. Position the trace to the bottom of the graticule with the vertical POSITION control.

h. CHECK—Deviation from straight line should not exceed 0.1 division.

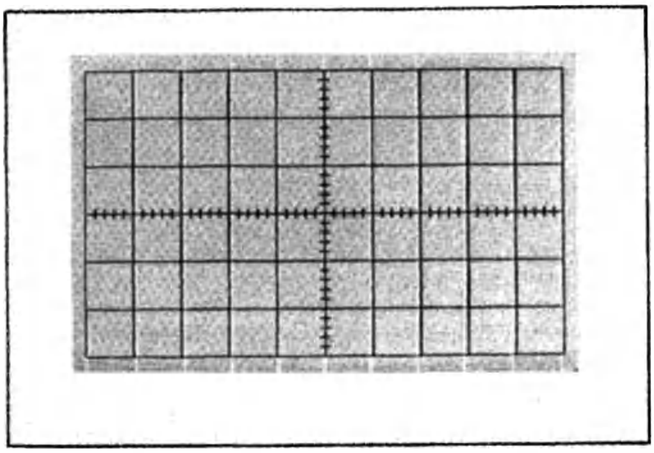


Fig. 5-2. Typical CRT display showing good geometry.

7. Check Limit Centering

REQUIREMENT—Less than 0.1 division compression or expansion of a center screen two-division signal when positioned to the top and bottom of the graticule area.

a. Set the VOLTS/DIV switch to 5 DIV CAL.

b. Position the bottom of the display to the first graticule line below the center horizontal line.

c. Reduce the display to exactly two divisions with the VARIABLE VOLTS/DIV control.

d. Position the top of the display to the top horizontal line of the graticule.

e. CHECK—Compression or expansion of signal 0.1 division or less.

f. Position the bottom of the display to the bottom horizontal line of the graticule.

g. CHECK—Compression or expansion of signal 0.1 division or less.

8. Check Vertical $\times 1$ Gain

REQUIREMENT—Five divisions of deflection at 0.1 VOLTS/DIV with 50-millivolt square-wave input.

a. Change the following control settings:

VOLTS/DIV	.01
VARIABLE VOLTS/DIV	CAL
Vertical POSITION	Midrange

b. Connect the standard amplitude calibrator (067-0502-00) output connector to the VERT INPUT connector with the 42-inch BNC cable.

c. Set the standard amplitude calibrator for a 50-millivolt square-wave output.

d. CHECK—CRT display for five divisions of deflection.

e. If necessary, adjust the VERT ×1 GAIN adjustment (on bottom) for exactly five divisions of deflection.

9. Check Vertical ×10 Gain

REQUIREMENT—Five divisions of deflection at 0.01 VOLTS/DIV with ×10 VERT GAIN switch pulled out and a five-millivolt square-wave input.

a. Set the standard amplitude calibrator for a five-millivolt square-wave output.

b. Pull the ×10 VERT GAIN switch.

c. CHECK—CRT display for five divisions of deflection.

d. If necessary, adjust the VERT ×10 GAIN adjustment (on bottom) for exactly five divisions of deflection.

10. Check Vertical Deflection Accuracy

REQUIREMENT—Vertical deflection within 3% of VOLTS/DIV switch indication.

a. Push the ×10 VERT GAIN switch in.

b. CHECK—Using the VOLTS/DIV switch and standard amplitude calibrator settings given in Table 5-1, check vertical deflection within 3% in each position of the VOLTS/DIV switch.

11. Check Variable Volts/Division Control Range

REQUIREMENT—Continuously variable deflection factor between the calibrated VOLTS/DIV steps.

a. Set the standard amplitude calibrator for a 50-millivolt square-wave output.

b. Change the following control settings:

VOLTS/DIV	.01
INPUT	AC

c. Center the display about the center horizontal line with the vertical POSITION control.

d. CHECK—Rotate the VARIABLE VOLTS/DIV control fully counterclockwise. Display must be reduced to two divisions or less (indicates adequate range for continuously variable deflection factor between the calibrated steps.)

12. Check Input Coupling Switch Operation

REQUIREMENT—Correct signal coupling in each position of the INPUT switch.

a. Set the VARIABLE VOLTS/DIV control to CAL.

b. Set the standard amplitude calibrator for a 20-millivolt square-wave output.

c. Center the display about the center horizontal line with the vertical POSITION control.

d. Set the INPUT switch to GND.

e. CHECK—CRT display for straight line near the center horizontal line.

f. Set the INPUT switch to DC.

g. CHECK—CRT display for square wave with the bottom near the center horizontal line.

h. Disconnect all test equipment.

13. Check Trace Shift Due To Input Current

REQUIREMENT—Trace shift neglible (0.085 division maximum).

TABLE 5-1

Vertical Deflection Accuracy

VOLTS/DIV switch setting	Standard amplitude calibrator output	Vertical deflection in divisions	Maximum Error for ±3% accuracy (divisions)
.01	50 millivolts	5	Previously set exactly in step 9
.02	0.1 volt	5	±0.15
.05	0.2 volt	4	±0.12
.1	0.5 volt	5	±0.15
.2	1 volt	5	±0.15
.5	2 volts	4	±0.12
1	5 volts	5	±0.15
2	10 volts	5	±0.15
5	20 volts	4	±0.12
10	50 volts	5	±0.15
20	100 volts	5	±0.15

a. Change the following control settings:

INPUT	GND
×10 VERT GAIN	Pulled out

b. Position the trace to the center horizontal line with the vertical POSITION control.

c. CHECK—Set the INPUT switch to DC. Trace shift should be neglible (0.085 division maximum).

14. Check Input Capacitance

REQUIREMENT—47 pF, ±4 pF.

a. Change the following control settings:

×10 VERT GAIN	Pushed in
TIME/DIV	.5 ms

b. Connect the square-wave generator (Type 106) high-amplitude output connector to the VERT INPUT connector through the GR to BNC adapter 10× BNC attenuator 42-inch 50-ohm BNC cable, 50-ohm BNC termination and 47 pF input RC normalizer, in given order.

c. Set the square-wave generator for a five-division display at one kilohertz.

d. CHECK—CRT display for 0.2 division, or less, overshoot or rounding (47 pF, ±4 pF).

e. Disconnect all test equipment.

15. Check Volts/Division Switch Compensation

REQUIREMENT—Optimum square corner and flat top within +3% or —3%, or total peak-to-peak aberrations not to exceed 3%.

a. Connect the P6049 Probe to the VERT INPUT connector.

b. Install the GR to BNC adapter 10× BNC attenuator and BNC post jack on the square-wave generator high-amplitude output connector in given order.

c. Connect the probe tip to the BNC post jack.

d. Set the square-wave generator for a five-division display at one kilohertz.

e. Compensate the probe as described in the probe instruction manual.

f. CHECK—CRT display at each VOLTS/DIV switch setting for optimum square corner and flat top within +3% or —3% or total peak-to-peak aberrations not to exceed 3%. Readjust the generator output and remove the attenuator as necessary to maintain a five-division display (pull the ×10 VERT GAIN switch for 5, 10 and 20 positions.

g. Disconnect all test equipment.

16. Check High-Frequency Compensation

REQUIREMENT—Optimum square-wave response with peak aberrations not to exceed +2% or —2%, or total aberrations not to exceed 3% peak to peak.

a. Change the following conrol settings:

×10 VERT GAIN	Pushed in
TIME/DIV	5 μs
×10 HORIZ MAG	Pulled out

b. Connect the square-wave generator fast-rise + output connector to the VERT INPUT connector through the GR to BNC adapter, 42-inch BNC cable, 10× BNC attenuator and the 50-ohm BNC termination.

c. Set the square-wave generator for a four-division display at 100 kilohertz.

d. Move the leading edge of the square-wave onto the viewing area with the horizontal POSITION control.

e. CHECK—CRT display for optimum square-wave response similar to Fig. 5-3 with peak aberrations not to exceed +2% or —2%, or total aberrations not to exceed 3% peak to peak.

f. Disconnect all test equipment.

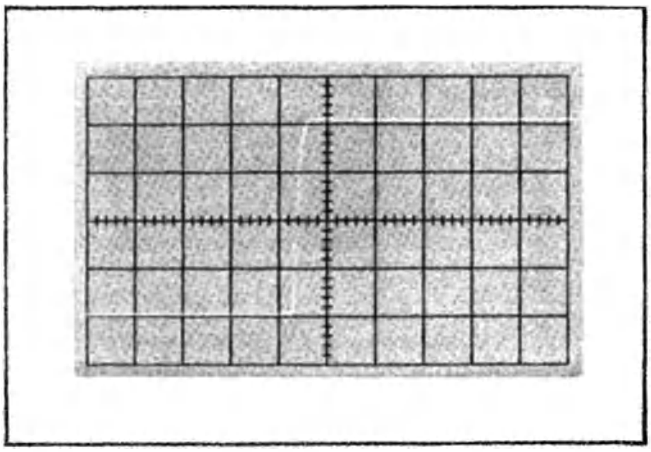


Fig. 5-3. Typical CRT display showing correct high-frequency compensation.

17. Check Upper Vertical Bandwidth Limit

REQUIREMENT—Not more than —3 dB at four megahertz.

a. Change the following control settings:

TIME/DIV	1 ms
×10 HORIZ MAG	Pushed in

b. Connect the high-frequency constant-amplitude sinewave generator (Type 191) to the VERT INPUT connector

through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 10× BNC attenuator and the 50-ohm BNC termination.

c. Set the constant-amplitude generator for a four-division display, centered about the center horizontal line, at its reference frequency (50 kilohertz).

d. Without changing the output amplitude, increase the output frequency of the generator until the display is reduced to 2.8 divisions (—3 dB point).

e. CHECK—Output frequency of generator must be four megahertz or higher.

18. Check ×10 Vertical Gain Upper Bandwidth Limit

REQUIREMENT—Not more than —3 dB at 2.75 megahertz.

a. Pull the ×10 VERT GAIN switch out.

b. Set the constant-amplitude generator for a four-division display, centered about the center horizontal line, at its reference frequency (50 kilohertz).

c. Without changing the output amplitude, increase the output frequency of the generator until the display is reduced to 2.8 divisions (—3 dB point).

d. CHECK—Output frequency of generator must be 2.75 megahertz or higher.

e. Disconnect all test equipment.

19. Check AC-Coupled Lower Vertical Bandwidth Limit

REQUIREMENT—Not more than —3 dB at two hertz.

a. Connect the low-frequency constant-amplitude generator to the VERT INPUT connector through the 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

b. Change the following control settings:

INPUT	AC
×10 VERT GAIN	Pushed in
TIME/DIV	.5 s

c. Set the low-frequency generator for a four-division display, centered about the center horizontal line, at a reference frequency of one kilohertz.

d. Without changing the output amplitude, reduce the output frequency of the generator to two hertz.

e. CHECK—CRT display 2.8 divisions, or greater, in amplitude (not more than —3 dB).

f. Disconnect all test equipment.

20. Check Magnifier Registration

REQUIREMENT—Less than one-division shift of marker at center vertical line when switching ×10 HORIZ MAG on (pulled out).

a. Change the following control settings:

VOLTS/DIV	.5
INPUT	DC
TIME/DIV	1 ms

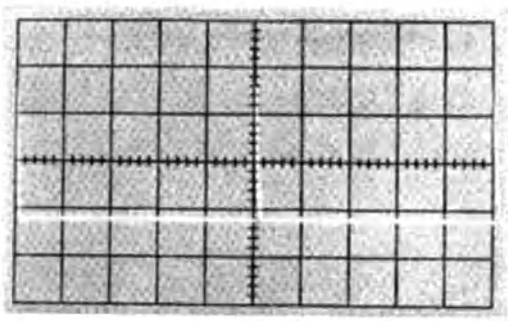
b. Connect the time-mark generator to the VERT INPUT connector through a 42-inch 50-ohm BNC cable and a 50-ohm BNC termination.

c. Set the time-mark generator for five-millisecond markers.

d. Position the middle marker (three markers on total magnified sweep) to the center vertical line (see Fig. 5-4A).

e. Pull the ×10 HORIZ MAG switch out. Be careful not to change the knob position as the ×10 HORIZ MAG switch is pulled out.

f. CHECK—Middle marker should be within one division of the center vertical line (see Fig. 5-4B).


(A)

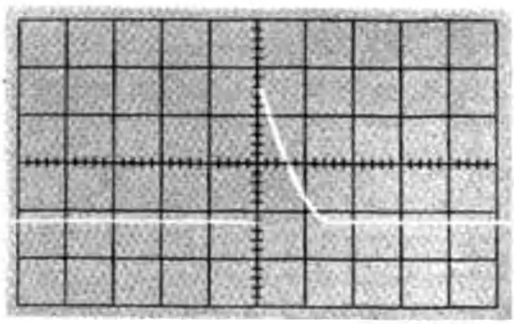

(B)

Fig. 5-4. Typical CRT display showing correct magnifier registration; (A) ×10 HORIZ MAG switch pushed in, (B) ×10 HORIZ MAG switch pulled out.

21. Check Normal Sweep Timing Accuracy

REQUIREMENT—5 μs to .2 s/DIV, within 3% over middle eight divisions of the display; .5 s and 1 s/DIV, within 4% over middle eight divisions of display.

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a. Push the ×10 HORIZ MAG switch in.

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-2, check normal sweep timing within the given tolerances over the middle eight divisions of the display. Set the TRIGGER control as necessary for a stable display in the variable positive-slope area. Fig. 5-5 shows a typical CRT display when checking sweep timing.

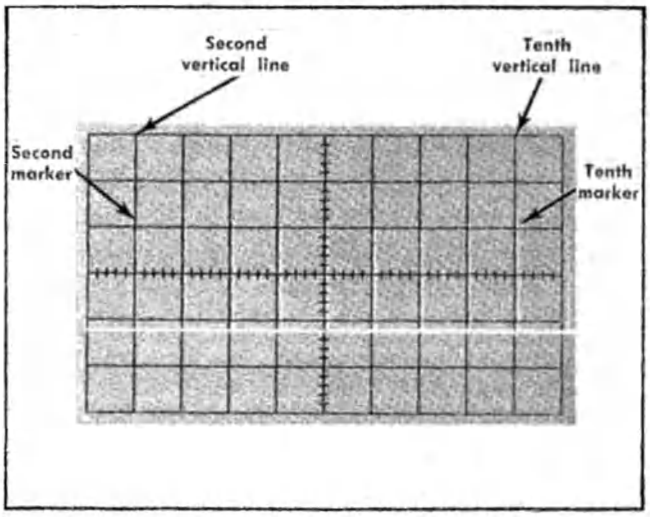


Fig. 5-5. Typical CRT display when checking normal sweep timing.

NOTE

Unless otherwise noted, use the middle eight horizontal divisions between second and tenth vertical lines of the graticule when checking timing.

22. Check Variable Time/Division Control Range

REQUIREMENT—Continuously variable sweep rate between the calibrated TIME/DIV switch settings.

a. Set the time-mark generator for 10-millisecond markers.

b. Set the TRIGGER control for a stable display in the variable positive-slope area.

c. Position the markers to the far left and right vertical lines of the graticule with the horizontal POSITION control.

d. Turn the VARIABLE TIME/DIV control fully counterclockwise.

e. CHECK—CRT display for four-division maximum spacing between markers (indicates adequate range for continuously variable sweep rates between the calibrated steps).

23. Check Sweep Length

REQUIREMENT—10.5 to 11 divisions.

a. Return the VARIABLE TIME/DIV control to CAL.

TABLE 5-2

Normal Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)	Allowable error for given accuracy
5 μs	5 microsecond	1	0.24 division (within 3%)
10 μs	10 microsecond	1	
20 μs	10 microsecond	2	
50 μs	50 microsecond	1	
.1 ms	0.1 millisecond	1	
.2 ms	0.1 millisecond	2	
.5 ms	0.5 millisecond	1	
1 ms	1 millisecond	1	
2 ms	1 millisecond	2	
5 ms	5 millisecond	1	
10 ms	10 millisecond	1	
20 ms	10 millisecond	2	
50 ms	50 millisecond	1	
.1 s	0.1 second	1	
.2 s	0.1 second	2	
.5 s	0.5 second	1	0.32 division (within 4%)
1 s	1 second	1	

b. Set the time-mark generator for one-millisecond markers.

c. Adjust the TRIGGER control for a stable display in the variable positive-slope area.

d. Move the eleventh marker (only part of the first marker may be visible) to the tenth vertical line with the horizontal POSITION control.

e. CHECK—Sweep length between 10.5 and 11 divisions as shown by 0.5 to one division of display to the right of the tenth vertical line.

24. Check Magnified Sweep Timing Accuracy

REQUIREMENT—20 μs to .2 s/DIV, within 4% over middle eight divisions of the CRT display with the ×10 HORIZ MAG switch pulled out; 5 and 10 μs/DIV and .5 and 1 s/DIV, within 5% over middle eight divisions of the CRT display with the ×10 HORIZ MAG switch pulled out. Check accuracy of each ten division portion of the total magnified sweep length within 4% at 1 ms/DIV.

a. Change the following control settings:

TRIGGER	Stable positive-slope triggering
Horizontal POSITION	Midrange
× HORIZ MAG	Pulled out

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-3, check magnified timing within the given tolerances over the middle eight-division portion of the total magnified sweep length. Set the TRIGGER control as necessary for a stable display in the variable positive-slope area.

c. Set the time-mark generator for 0.1-millisecond markers.

d. Set the TIME/DIV switch to 1 ms.

e. Position the first ten-division portion of the total magnified sweep onto the viewing area with the horizontal POSITION control.

f. CHECK—One marker each division between the second and tenth vertical lines. Marker at tenth vertical line must be within 0.32 division (within 4%) of that line when the marker at the second vertical line is positioned exactly.

g. Repeat this check for each ten division portion of the total magnified sweep length.

TABLE 5-3

Magnified Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)	Allowable error for given accuracy
5 μs	0.5 microsecond	1	0.4 division
10 μs	1 microsecond	1	(within 5%)
20 μs	1 microsecond	2	0.32 division
50 μs	5 microsecond	1	(within 4%)
.1 ms	10 microsecond	1	
.2 ms	10 microsecond	2	
.5 ms	50 microsecond	1	
1 ms	0.1 millisecond	1	
2 ms	0.1 millisecond	2	
5 ms	0.5 millisecond	1	
10 ms	1 millisecond	1	
20 ms	1 millisecond	2	
50 ms	5 millisecond	1	
.1 s	10 millisecond	1	
.2 s	10 millisecond	2	
.5 s	50 millisecond	1	0.4 division
1 s	0.1 second	1	(within 5%)

25. Check External Horizontal Variable Balance

REQUIREMENT—No trace shift as EXT HORIZ VAR control is rotated throughout its range.

a. Change the following control settings:

INPUT	GND
Trig/Horiz Coupling	EXT TRIG OR HORIZ DC
EXT TRIG OR HORIZ ATTEN	1×
TIME/DIV	EXT HORIZ

b. Position the dot to the center of the graticule with the POSITION controls.

c. CHECK—Rotate the EXT HORIZ VAR control (VARIABLE TIME/DIV) throughout its range. Dot should not move horizontally.

26. Check External Horizontal Deflection Factor

REQUIREMENT—200 to 300 millivolts/division.

a. Change the following control settings:

EXT HORIZ VAR	CAL (clockwise)
×10 HORIZ MAG	Pushed in

b. Position the dot to the left vertical line of the graticule with the horizontal POSITION control.

c. Connect the standard amplitude calibrator to the EXT TRIG OR HORIZ INPUT connector with the 42-inch BNC cable.

d. Set the standard amplitude calibrator for a two-volt square-wave output.

e. CHECK—CRT display for horizontal deflection of 6.7 to 10 divisions between dots (200 to 300 millivolts/division).

27. Check External Horizontal Deflection Factor with 10× Attenuation

REQUIREMENT—Two to three volts/division.

a. Set the EXT TRIG OR HORIZ ATTEN switch (side panel) to 10×.

b. Set the standard amplitude calibrator for a 20-volt square-wave output.

c. CHECK—CRT display for horizontal deflection of 6.7 to 10 divisions between dots (two to three volts/division).

28. Check External Horizontal Variable Control Range

REQUIREMENT—10:1 range, or greater.

a. Turn the EXT HORIZ VAR control fully counterclockwise.

b. CHECK—CRT display not more than one-tenth of the deflection measured in previous step (10:1 range, or greater).

29. Check External Horizontal Coupling

REQUIREMENT—Correct signal coupling in the EXT TRIG OR HORIZ positions of the Trig/Horiz Coupling switch.

a. Position the left dot of the display to the center vertical line with the horizontal POSITION control.

b. Set the Trig/Horiz Coupling switch to EXT TRIG AC.

c. CHECK—CRT display for horizontal deflection centered about the center vertical line.

d. Disconnect all test equipment.

30. Check External Horizontal Bandwidth

REQUIREMENT—Not more than —3 dB at 10 kilohertz.

a. Change the following control settings:

EXT TRIG OR HORIZ ATTEN	1×
EXT HORIZ VAR	CAL (fully clockwise)

b. Connect the low-frequency sine-wave generator to the EXT TRIG OR HORIZ INPUT connector through the 42-inch 50-ohm BNC cable and 50-ohm BNC termination.

c. Set the low-frequency generator for a six-division horizontal deflection, centered about the center vertical line, at one kilohertz.

d. Without changing the output amplitude, increase the output frequency of the generator to 10 kilohertz.

e. CHECK—CRT display 4.2 divisions, or greater, horizontal deflection (not more than —3 dB).

31. Check External Blanking

REQUIREMENT—Five-volt positive peak signal blanks trace.

a. Change the following control settings:

VOLTS/DIV	2
INPUT	DC
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	5 μs

b. Connect the low-frequency generator to the VERT INPUT connector through the 42-inch BNC cable and the BNC T connector.

c. Set the low-frequency generator for a five-division display (five volt positive peaks) at 100 kilohertz.

d. Connect the output of the BNC T connector to the EXT BLANK jack with the six-inch BNC to banana plug patch cord.

e. CHECK—CRT display for blanking of a portion of each cycle of the waveform (see Fig. 5-6). The INTENSITY control setting may need to be changed to show blanking.

f. Disconnect all test equipment.

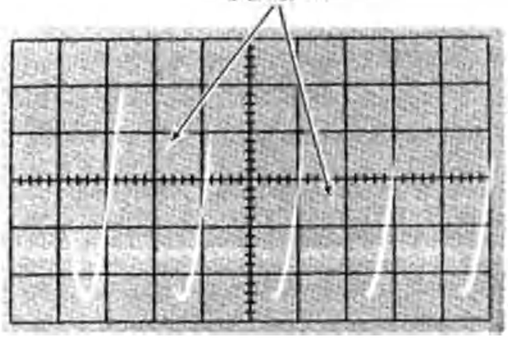


Fig. 5-6. Typical CRT display when checking external blanking.

32. Check Internal Triggering Operation

REQUIREMENT—Stable display in INT TRIG AC and ACLF REJ positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and — AUTO; check with 0.3-division display at 400 kilohertz and a 0.75-division display at four megahertz.

a. Change the following control settings:

VOLTS/DIV	.1
TRIGGER	+ AUTO
TIME/DIV	5 μs

b. Connect the high-frequency constant-amplitude sinewave generator to the VERT INPUT connector through the GR to BNC adapter 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG OR HORIZ INPUT connector with a 42-inch 50-ohm BNC cable.

c. Set the constant-amplitude generator for a 0.3-division display at 400 kilohertz.

d. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

e. Turn the TRIGGER control clockwise to the variable positive-slope area.

f. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

g. Turn the TRIGGER control clockwise to the variable negative-slope area.

h. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

i. Set the TRIGGER control to — AUTO.

j. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

k. Set the constant-amplitude generator for a 0.75-division display at four megahertz.

l. Pull the ×10 HORIZ MAG switch out.

m. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

n. Turn the Trigger control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

r. Set the TRIGGER control to + Auto.

s. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

33. Check External Triggering Operation

REQUIREMENT—Stable display in EXT TRIG OR HORIZ AC and DC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and — AUTO; check with a 75-millivolt signal at 400 kilohertz and a 190-millivolt signal at four megahertz.

a. Change the following control settings:

Trig/Horiz Coupling	EXT TRIG OR HORIZ AC
×10 HORIZ MAG	Pushed in

b. Set the constant-amplitude generator for a 0.75-division display (75 millivolts) at 400 kilohertz.

c. CHECK—Stable CRT display is presented.

d. Turn the TRIGGER control clockwise to the variable positive-slope area.

e. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

f. Turn the TRIGGER control clockwise to the variable negative-slope area.

g. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

h. Set the TRIGGER control to — AUTO.

i. CHECK—Stable CRT display is presented.

j. Set the constant-amplitude generator for a 1.9-division display (190 millivolts) at 400 kilohertz.

k. Without changing the output amplitude, set the generator to four megahertz.

l. Pull the ×10 HORIZ MAG switch out.

m. CHECK—Stable CRT display is presented.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

r. Set the TRIGGER control to + AUTO.

s. CHECK—Stable CRT display is presented.

t. Disconnect the high-frequency generator.

34. Check Low-Frequency Triggering Operation

REQUIREMENT—External, stable display in EXT TRIG OR HORIZ AC and DC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and — AUTO; check with 75-millivolt signal at 30 hertz. Internal, stable display in INT TRIG AC position of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and — AUTO; check with a 0.3-division display at 30 hertz.

a. Connect the low-frequency constant amplitude sine-wave generator to the VERT INPUT connector through the 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG OR HORIZ INPUT connector with a 42-inch 50-ohm BNC cable.

b. Change the following control settings:

TIME/DIV	10 ms
×10 HORIZ MAG	Pushed in

c. Set the low-frequency generator for a 0.75-division display (75 millivolts) at 30 hertz.

d. CHECK—Stable CRT display is presented.

e. Turn the TRIGGER control clockwise to the variable positive-slope area.

f. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

g. Turn the TRIGGER control clockwise to the variable negative-slope area.

h. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

i. Set the TRIGGER control to — AUTO.

j. CHECK—Stable CRT display is presented.

k. Set the Trig/Horiz Coupling switch to INT TRIG AC.

l. Set the low-frequency generator for a 0.3-division display at 30 hertz.

m. CHECK—Stable CRT display is presented.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the TRIGGER control.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the TRIGGER control.

r. Set the TRIGGER control to + AUTO.

s. CHECK—Stable CRT display is presented.

35. Check Low-Frequency Reject Operation

REQUIREMENT—Stable display with 0.3-division display at 30 kilohertz with the TRIGGER control set to + and — AUTO and in the variable positive and negative slope areas; stable display cannot be obtained at 30 hertz.

a. Change the following control settings:

Trig/Horiz Coupling	INT TRIG ACLF REJ
TIME/DIV	.1 ms

b. Set the low-frequency generator for a 0.3-division display at 30 kilohertz.

c. CHECK—Stable CRT display can be obtained with the TRIGGER control set to + and — AUTO and in the variable positive and negative slope areas (adjust as necessary).

d. Without changing the output amplitude, set the low-frequency generator to 30 hertz.

e. Set the TIME/DIV switch to 10 ms.

f. CHECK—Stable CRT display cannot be obtained at any setting of the TRIGGER control.

36. Check Trigger Slope Operation

REQUIREMENT—Stable triggering on correct slope of trigger signal in the + AUTO, variable positive-slope area, variable negative-slope area and — AUTO positions of the TRIGGER control.

a. Change the following control settings:

TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	.5 ms

b. Set the low-frequency generator for a four-division display at one kilohertz.

c. CHECK—CRT display starts on the positive slope of the waveform.

d. Turn the TRIGGER control clockwise until a stable display is obtained in the positive-slope area.

e. CHECK—CRT display starts on the positive slope of the waveform.

f. Turn the TRIGGER control clockwise until a stable display is obtained in the negative-slope area.

g. CHECK—CRT display starts on the negative slope of the waveform.

h. Set the TRIGGER control to — AUTO.

i. CHECK—CRT display starts on the negative slope of the waveform.

37. Check TRIGGER Control Range

REQUIREMENT—EXT TRIG OR HORIZ ATTEN switch set to 1×, at least + and — 0.8 volts; EXT TRIG OR HORIZ ATTEN switch set to 10X, at least + and — 8 volts.

a. Remove the 50-ohm BNC termination and reconnect the low frequency sine-wave generator to the BNC T connector through the 42-inch BNC cable.

b. Change the following control settings:

VOLTS/DIV	.5
TRIGGER	+ AUTO
Trig/Horiz Coupling	EXT TRIG AC

c. Set the low-frequency generator for a 3.2-division display (1.6 volts peak to peak) at one kilohertz.

d. CHECK—Rotate the TRIGGER control throughout the positive-slope area and check that the display can be triggered (stable display) at any point along the positive slope of the waveform (indicates TRIGGER control range of at least + and — 0.8 volt). Display is not triggered at either extreme of the positive-slope area except in + AUTO detent.

e. CHECK—Rotate the TRIGGER control throughout the negative-slope area and check that the display can be triggered at any point along the negative slope of the waveform. Display is not triggered at either extreme of the negative-slope area except in the — AUTO detent.

f. Change the following control settings:

VOLTS/DIV	5
TRIGGER	+ AUTO
EXT TRIG OR HORIZ ATTEN	10×

g. Set the low-frequency generator for a 3.2-division display (16 volts peak to peak) at one kilohertz.

h. CHECK—Rotate the TRIGGER control throughout the positive-slope area and check that the display can be triggered at any point along the positive slope of the wavefrom. Display is not triggered at either extreme of the positive-slope area except in + AUTO detent.

i. CHECK—Rotate the TRIGGER control throughout the negative-slope area and check that the display can be triggered at any point along the negative slope of the waveform. Display is not triggered at either extreme of the negative-slope area except in — AUTO detent.

j. Disconnect all test equipment.

38. Check Calibrator Risetime

REQUIREMENT—Two microseconds or less.

a. Change the following control settings:

VOLTS/DIV	5 DIV CAL
TRIGGER	— AUTO
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	.1 ms
X10 HORIZ MAG	Pulled out

b. Position the rising portion of the waveform onto the viewing area with the horizontal POSITION control and center the display with the vertical POSITION control.

c. CHECK—CRT display for 0.2 division or less horizontal distance between the 10% and 90% points on the lead-

ing edge of the calibrator waveform (two microseconds or less risetime).

39. Check Calibrator Repetition Rate

REQUIREMENT—750 hertz, ±250 hertz.

a. Change the following control settings:

TRIGGER	+ AUTO
TIME/DIV	.2 ms
X10 HORIZ MAG	Pushed in

b. Position the start of the trace to the left vertical line of the graticule.

c. CHECK—CRT display for duration of one cycle between 5 and 10 divisions (repetition rate 750 hertz, ±240 hertz).

40. Check Calibrator Duty Cycle

REQUIREMENT—40% to 60%.

a. Set the TIME/DIV switch to .1 ms.

b. Set the VARIABLE TIME/DIV control for one complete cycle in 10 divisions.

c. CHECK—CRT display for length of positive segment of the square wave between four and six divisions (duty cycle 40% to 60%).

41. Check Calibrator Voltage Output

REQUIREMENT—0.5 volt, ±1%.

a. Change the following control settings:

VOLTS/DIV	.1
TIME/DIV	5 ms
VARIABLE TIME/DIV	CAL

b. Connect the CAL OUT connector (side panel) to the unknown input connector of the standard amplitude calibrator with the 18-inch BNC to banana plug patch cord.

c. Set the standard amplitude calibrator for a positive 0.5 volt DC output in the mixed mode.

d. Connect the standard amplitude calibrator output connector to the VERT INPUT connector with a 42-inch BNC cable.

e. Set the TRIGGER control for a stable display.

f. Position the top of the waveform onto the display area with the vertical POSITION control.

g. CHECK—Difference between the standard amplitude calibrator output level and the Type 323 calibrator output level is 0.05 division (about one trace width) or less (0.5 volt, ±1%; see Fig. 5-7).

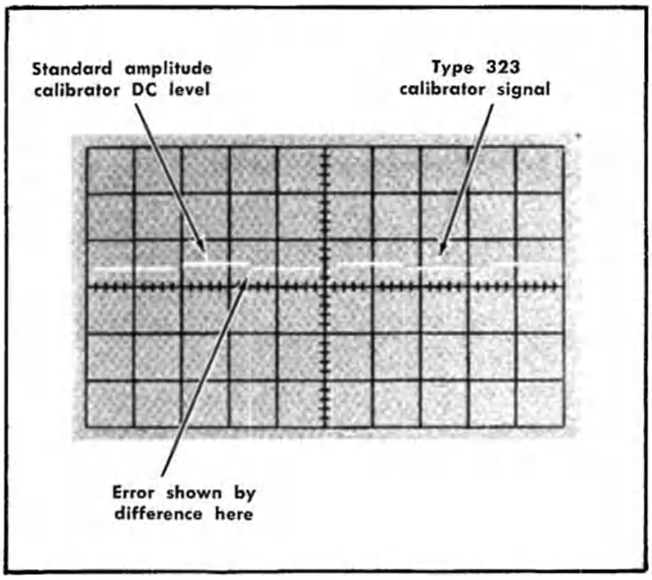


Fig. 5-7. Typical CRT display when checking voltage output of calibrator.

NOTE

The procedure given in step 4 of the Calibration section (Section 6) provides a more accurate method of checking the voltage at the CAL OUT jack.

This completes the performance check of the Type 323. If the instrument has met all performance requirements given in this procedure, it is correctly calibrated and within the specified tolerances.

SECTION 6
CALIBRATION

Change information, if any, affecting this section will be found at the rear of the manual.

Introduction

Complete calibration information for the Type 323 is given in this section. This procedure calibrates the instrument to the performance requirements listed in Section 1 of this manual. Completion of each step in this procedure returns the Type 323 to its orignal performance standards. If it is desired to merely touch up the calibration, perform only those steps entitled "Adjust . . . ". A short-form calibration procedure is also provided in this section for the convenience of the experienced calibrator.

To assure accurate measurements and correct operation, check the calibration of the Type 323 after each 500 hours of operation, or every six months if used infrequently. Before performing a complete calibration, thoroughly clean and inspect the instrument as outlined in the Maintenance section. The Performance Check section provides a complete check of instrument performance without making internal adjustments. Use the performance check procedure to verify the calibration of the Type 323 and/or to determine if recalibration is required.

TEST EQUIPMENT REQUIRED

General

The following test equipment and accessories, or its equivalent, is required for complete calibration of the Type 323. Specifications given are the minimum necessary for accurate calibration. Therefore, some of the recommended equipment may have specifications which exceed those given. All test equipment is assumed to be correctly calibrated and operating within the given specifications. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

For the quickest and most accurate calibration, special Tektronix calibration fixtures are used where necessary. These special calibration fixtures are available from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

Test Equipment

1. Precision DC voltmeter. Accuracy, within ±0.1%; range, zero to 200 volts. For example, Fluke Model 825A Differential DC Voltmeter.

2. DC voltmeter (VOM)[1]. Minimum sensitivity, 10,000 ohms/volt; accuracy, checked to within 1% at —1900 volts. For example, Triplett Model 630-NA.

[1]If a precision voltage divider is available for use with the precision DC voltmeter (such as Fluke 80E-2 Voltage Divider), it is recommended for more accurate adjustment of the high-voltage supply.

3. Variable DC power supply. Voltage range, at least +6 to +16 volts; current capability, at least 0.75 ampere; output voltage measured within 3% except where noted. For example, Trygon Model HR40-750.

4. Test oscilloscope. Bandwidth, DC to 10 megahertz; minimum deflection factor, 10 millivolts/division; accuracy, within 3%. Tektronix Type 561A Oscilloscope with Type 3A6 Amplifier unit and Type 3B4 Time Base unit recommended.

5. Time-mark generator. Marker outputs, 0.5 microsecond to five seconds; marker accuracy, within 0.1%. Tektronix Type 184 Time-mark Generator recommended.

6. Standard amplitude calibrator. Amplitude accuracy, within 0.25%; signal amplitude, five millivolts to 100 volts; output signal, square wave. Tektronix calibration fixture 067-0502-00 recommended.

7. Square-wave generator. Must have the following output capabilities (may be obtained from separate generators): 120 volts amplitude at one kilohertz repetition rate with a one microsecond risetime; 500 millivolts into 50 ohms at one kilohertz and one megahertz repetition rates with a 50 nanosecond risetime. Tektronix Type 106 Square-Wave Generator recommended (meets both output requirements).

8. High-frequency constant-amplitude sine-wave generator. Frequency, 350 kilohertz to above four megahertz; reference frequency, 50 kilohertz; output amplitude, variable from five millivolts to 0.5 volt into 50 ohms; amplitude accuracy, constant within 3% at 50 kilohertz and from 350 kilohertz to above four megahertz. Tektronix Type 191 Constant Amplitude Signal Generator recommended.

9. Low-frequency constant-amplitude sine-wave generator. Frequency, two hertz to 100 kilohertz; output amplitude, variable from 50 millivolts to 16 volts peak to peak; amplitude accuracy, constant within 3% from two hertz to 100 kilohertz. For example, General Radio 1310-A Oscillator (use a General Radio Type 274QBJ Adaptor to provide BNC output).

Accessories

10. AC power cord. Fits AC POWER jack of Type 323. Tektronix Part No. 161-0043-00 (supplied accessory).

11. Patch cord (two). Length, 18 inches; connectors, banana plug-jack on both ends. Tektronix Part No. 012-0031-00.

12. 1× Probe with BNC connector. Tektronix P6011 Probe recommended.

13. Cable (two). Impedance, 50 ohms; type, RG-58/U; length, 42 inches; connectors, BNC. Tektronix Part No. 012-0057-01.

14. Calibration shield. Tektronix calibration fixture 067-0571-00.

15. Adapter. Adapts GR874 connector to BNC male connector. Tektronix Part No. 017-0063-00.

16. Termination. Impedance, 50 ohms; accuracy, ±3%, connectors, BNC. Tektronix Part No. 011-0049-00.

17. 10× attenuator. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0059-00.

18. Input RC normalizer. Time constant, 1 megohm × 47 pF; attenuation, 2×; connectors, BNC. Tektronix calibration fixture 067-0541-00.

19. 10× probe for Type 323. Tektronix P6049 Probe recommended (supplied accessory).

20. BNC post jack. Tektronix Part No. 012-0092-00.

21. 10× probe for test oscilloscope. Tektronix P6006 Probe recommended.

22. BNC T connector. Tektronix Part No. 103-0030-00.

23. Patch cord. Length, six inches; connectors, banana plug-jack and BNC male. Tektronix Part No. 012-0089-00 (supplied accessory).

Adjustment Tools

24. Screwdriver. Three-inch shaft, $^3/_{32}$-inch bit for slotted screws. Tektronix Part No. 003-0192-00.

25. Low-capacitance screwdriver. $1^1/_2$-inch shaft. Tektronix Part No. 003-0000-00.

SHORT-FORM CALIBRATION PROCEDURE

This short-form calibration procedure is provided to aid in the calibration of the Type 323. It may be used as a calibration guide by the experienced calibrator, or it may be reproduced and used as a permanent record of calibration. Since the step numbers and titles used here correspond to those used in the complete procedure, this procedure also serves as an index to locate a step in the complete Calibration Procedure. Performance requirements listed here correspond to those given in Section 1 of this manual.

Type 323, Serial No. ____________________

Calibration Date ____________________

Calibrated by ____________________

☐ 1. Adjust Charging Current (R644) — Page 6-6

54 millivolts, ± millivolts across R615 at FULL CHG. Check for about 20 millivolts across R615 at TRICKLE CHG.

☐ 2. Adjust High-Voltage Supply and Check Regulation (R513) — Page 6-7

—1900 volts, ±38 volts. Must maintain this tolerance over DC power input range.

☐ 3. Adjust Intensity Limit (R583) — Page 6-7

1.00 volt, ±0.05 volt at point K on Power Regulator board.

☐ 4. Adjust +5-Volt Power Supply (CAL OUT Voltage) (R552) — Page 6-8

Adjust for +0.500 volt, ±2.5 millivolts, at CAL OUT jack with Q9 removed. Check for +5.0 volts, ±0.1 volt, output from supply.

☐ 5. Adjust —5-Volt Power Supply (R566) — Page 6-8

—5 Volts, ±0.1 volt.

☐ 6. Check +14-Volt and +175-Volt Power Supplies — Page 6-8

+14-Volt Supply, ±2.8 volts

+100-Volt Supply, ±5 Volts

+175-Volt Supply, +14 or —7 volts.

☐ 7. Check Low-Voltage Power Supply Ripple — Page 6-8

Power supply	Maximum ripple over DC power input range
—5-Volt	10 millivolts
+5-Volt	10 millivolts
+14-Volt	150 millivolts
+100-Volt	150 millivolts
+175-Volt	500 millivolts

☐ 8. Check Low-Voltage Power-Supply Regulation — Page 6-8

Power supply	Maximum output change of supply (regulation) over DC power input range
—5-Volt	±0.03 volt
+5-Volt	±0.025 volt
+14-Volt	±2.8 volts
+100-Volt	±5.0 volts
+175-Volt	±14 volts

☐ 9. Check Low Batteries Indicator — Page 6-9
LOW BATT light flashes with DC input voltage of 6.25 volts, ±0.31 volt.

☐ 10. Adjust Variable Volts/Division Balance (R40) — Page 6-9

Less than one division vertical trace shift as the VARIABLE VOLTS/DIV control is rotated throughout its range.

☐ 11. Adjust Vertical ×10 Balance (R39) — Page 6-9

Less than 1.5 division vertical trace shift as the ×10 VERT GAIN switch is pulled out.

☐ 12. Adjust Deflection Plate DC level (R91, R93) — Page 6-9

Voltage range at the collectors of Q163 and Q173 as the vertical POSITION control is rotated throughout its range centered about +50 volts.

- [ ] 13. Adjust Astigmatism (R597) — Page 6-11

  Best definition of marker display.

- [ ] 14. Adjust Trace Alignment (R592) — Page 6-11

  Trace parallel to horizontal graticule lines.

- [ ] 15. Adjust CRT Geometry (R593) — Page 6-11

  0.1 division, or less, curvature of markers.

- [ ] 16. Adjust Limit Centering (R66) — Page 6-12

  Minimum compression of a center screen two-division signal when positioned to the top and bottom of the graticule area. Compression or expansion should not exceed 0.1 division.

- [ ] 17. Adjust Vertical ×1 Gain (R69) — Page 6-12

  Five divisions of deflection at 0.01 VOLTS/DIV with 50-millivolt square-wave input.

- [ ] 18. Adjust Vertical ×10 Gain (R46) — Page 6-12

  Five divisions of deflection at 0.1 VOLTS/DIV with ×10 VERT GAIN switch pulled out and a five-millivolt square-wave input.

- [ ] 19. Check Vertical Deflection Accuracy — Page 6-12

  Vertical deflection within 3% of VOLTS/DIV switch indication.

- [ ] 20. Check Variable Volts/Division Control Range — Page 6-12

  Continuously variable deflection factor between the calibrated VOLTS/DIV steps.

- [ ] 21. Check Input Coupling Switch Operation — Page 6-12

  Correct signal coupling in each position of the INPUT switch.

- [ ] 22. Check Trace Shift Due to Input Current — Page 6-13

  Trace shift negligible (0.085 division maximum).

- [ ] 23. Check Input Capacitance — Page 6-14

  47 pF, ±4 pF.

- [ ] 24. Adjust Volts/Division Compensation — Page 6-14

  (C23A, C23B, C24A, C24B, C25A, C25B, C28A, C28B, C29A, C29B)

  Optimum square corner and flat top within +3% or −3%, or total peak-to-peak aberrations not to exceed 3% with one-kilohertz square wave.

- [ ] 25. Adjust Internal Trigger Compensation (C201) — Page 6-15

  Optimum square-wave response similar to Fig. 6-11A through internal trigger pickoff.

- [ ] 26. Adjust External Trigger Compensation (C206) — Page 6-16

  Optimum square-wave response for external trigger signals with EXT TRIG OR HORIZ ATTEN set to 10×.

- [ ] 27. Adjust High-Frequency Compensation (C160, C170) — Page 6-17

  Optimum square-wave response at 100 kilohertz with peak aberrations not to exceed +2% or −2%, or total aberrations not to exceed 3% peak to peak.

- [ ] 28. Check Upper Vertical Bandwidth Limit — Page 6-18

  Not more than −3 dB at four megahertz.

- [ ] 29. Check ×10 Vertical Gain Upper Bandwidth Limit — Page 6-18.

  Not more than −3 dB at 2.75 megahertz.

- [ ] 30. Check AC-Coupled Lower Vertical Bandwidth Limit — Page 6-17

  Not more than −3 dB at two hertz.

- [ ] 31. Adjust Magnifier Registration (R439) — Page 6-19

  Less than one-division shift of marker at center vertical line when switching ×10 HORIZ MAG on (pulled out).

- [ ] 32. Adjust Normal Timing (R401) — Page 6-20

  Correct timing at 1 ms/DIV over middle eight divisions of the display.

- [ ] 33. Check Variable Time/Division Control Range — Page 6-20

  Continuously variable sweep rate between the calibrated TIME/DIV switch settings.

- [ ] 34. Adjust Sweep Length (R347) — Page 6-20

  10.5 to 11 divisions.

- [ ] 35. Adjust Magnified Timing (R433) — Page 6-20

  Correct timing at 1 ms/DIV position of TIME/DIV switch with 10× HORIZ MAG switch pulled out. Accuracy of each ten division portion of total magnified sweep length within 4%.

- [ ] 36. Adjust High-Speed Timing (C446, C454, C432) — Page 6-21

  Optimum linearity and timing at 10 and 5 μs/DIV positions of TIME/DIV switch (×10 HORIZ MAG switch pulled out).

- [ ] 37. Check Normal Sweep Timing Accuracy — Page 6-22

  5 μs to .2 s/DIV, within 3% over middle eight divisions of the display; .5 s and 1 s/DIV, within 4% over middle eight divisions of the display.

- [ ] 38. Check Magnified Sweep Timing Accuracy — Page 6-22

  20 μs to .2 s/DIV, within 4% over middle eight divisions of the CRT display with the ×10 HORIZ MAG switch pulled out; 5 and 10 μs/DIV and .5 and 1 s/DIV, within 5% over middle eight divisions of the CRT display with the ×10 HORIZ MAG switch pulled out.

☐ 39. Adjust External Horizontal Variable Balance (R218) — Page 6-23

No trace shift as EXT HORIZ VAR control is rotated throughout its range.

☐ 40. Check External Horizontal Deflection Factor — Page 6-23

200 to 300 millivolts/division.

☐ 41. Check External Horizontal Deflection Factor with 10× Attenuation — Page 6-24

Two to three volts/division.

☐ 42. Check External Horizontal Variable Control Range — Page 6-24

10:1 range or greater.

☐ 43. Check External Horizontal Coupling — Page 6-24

Correct signal coupling in the EXT TRIG OR HORIZ positions of the Trig/Horiz Coupling switch.

☐ 44. Check External Horizontal Bandwidth — Page 6-24

Not more than −3 dB at 10 kilohertz.

☐ 45. Check External Blanking — Page 6-24

Five-volt positive peak signal blanks trace.

☐ 46. Check Internal Triggering Operation — Page 6-25

Stable display in INT TRIG AC and ACLF REJ positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and − AUTO; check with 0.3-division display at 400 kilohertz and a 0.75-division display at four megahertz.

☐ 47. Check External Triggering Operation — Page 6-26

Stable display in EXT TRIG OR HORIZ AC and DC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and − AUTO; check with a 75-millivolt signal at 400 kilohertz and a 190-millivolt signal at four magahertz.

☐ 48. Check Low-Frequency Triggering Operation — Page 6-26

External, stable display in EXT TRIG OR HORIZ AC and DC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, negative-slope area and − AUTO; check with 75-millivolt signal at 30 hertz. Internal, stable display in INT TRIG OR HORIZ AC positions of the Trig/Horiz Coupling switch with the TRIGGER control set to + AUTO, variable positive-slope area, variable negative-slope area and − AUTO; check with a 0.3-division display at 30 hertz.

☐ 49. Check Low-Frequency Reject Operation — Page 6-27

Stable display with 0.3-division display at 30 kilohertz with the TRIGGER control set to + and − AUTO and in the variable positive- and negative-slope areas; stable display cannot be obtained at 30 hertz.

☐ 50. Check Trigger Slope Operation — Page 6-27

Stable triggering on correct slope of trigger signal in the + AUTO, variable positive-slope area, variable negative-slope area and − AUTO positions of the TRIGGER control.

☐ 51. Check TRIGGER Control Range — Page 6-27

EXT TRIG OR HORIZ ATTEN switch set to 1×, at least + and −0.8 volts; EXT TRIG OR HORIZ ATTEN switch set to 10×, at least + and − 8 volts.

☐ 52. Check Calibrator Risetime — Page 6-28

Two microseconds or less.

☐ 53. Check Calibrator Repetition Rate — Page 6-28

750 hertz, ±250 hertz.

☐ 54. Check Calibrator Duty Cycle — Page 6-28

40% to 60%.

CALIBRATION PROCEDURE

General

The following procedure is arranged in a sequence which allows the Type 323 to be calibrated with the least interaction of adjustments and reconnection of equipment. The steps in which adjustments are made are identified by the symbol ◐ following the title. Whenever possible, instrument performance is checked in the "CHECK" part of the step before an adjustment is made. The "ADJUST" part of the step identifies the point where the actual adjustment is made. Steps listed in the "INTERACTION" part of the step may be affected by the adjustment just performed. This is particularly helpful when only a partial calibration procedure is performed.

NOTE

To prevent recalibration of other parts of the instrument when performing a partial calibration, readjust only if the tolerances given in the CHECK part of the step are not met. However, when performing a complete calibration, best overall performance is obtained if each adjustment is made to the exact setting even if the CHECK is within the allowable tolerance.

In the following procedure, a test-equipment setup picture is shown for each major group of checks and adjustments. Beneath this setup picture is a complete list of front-panel control settings for the Type 323. To aid in locating individual controls which have been changed for the new setup, these control names are printed in bold type. Each step continues from the equipment setup and control settings used in the preceding step(s) unless noted otherwise. If only a partial calibration is performed, start with the test equipment setup preceding the desired portion. External controls or adjustments of the Type 323 referred to in this procedure are capitalized (e.g., VOLTS/DIV). Internal adjustment names are initial capitalized only (e.g., Limit Centering).

All waveforms shown in this procedure are actual waveform photographs taken directly from the graticule. The following procedure uses the equipment listed under Test Equipment Required. If equipment is substituted, control settings or test equipment setup may need to be altered to meet the requirements of the equipment used. Detailed operating instructions for the test equipment are not given in this procedure. If in doubt as to the correct operation of any of the test equipment, refer to the instruction manual for that unit.

Preliminary Procedure for Complete Calibration

1. Remove the cabinet from the Type 323.

2. Remove the high-voltage cover and power pack from the Type 323. Removal instructions are given in the Maintenance section of this manual.

3. Using the AC power cord, connect the power pack of the Type 323 to an AC line voltage source which is within the voltage and frequency requirements of this instrument.

NOTE

For this instrument to meet the performance requirements as given in Section 1 over the entire operating temperature range, it must be calibrated between +20°C and +30°C. However, the instrument can be calibrated at any temperature (within the −15°C to +55°C range) to meet the applicable performance requirements at the calibration temperature.

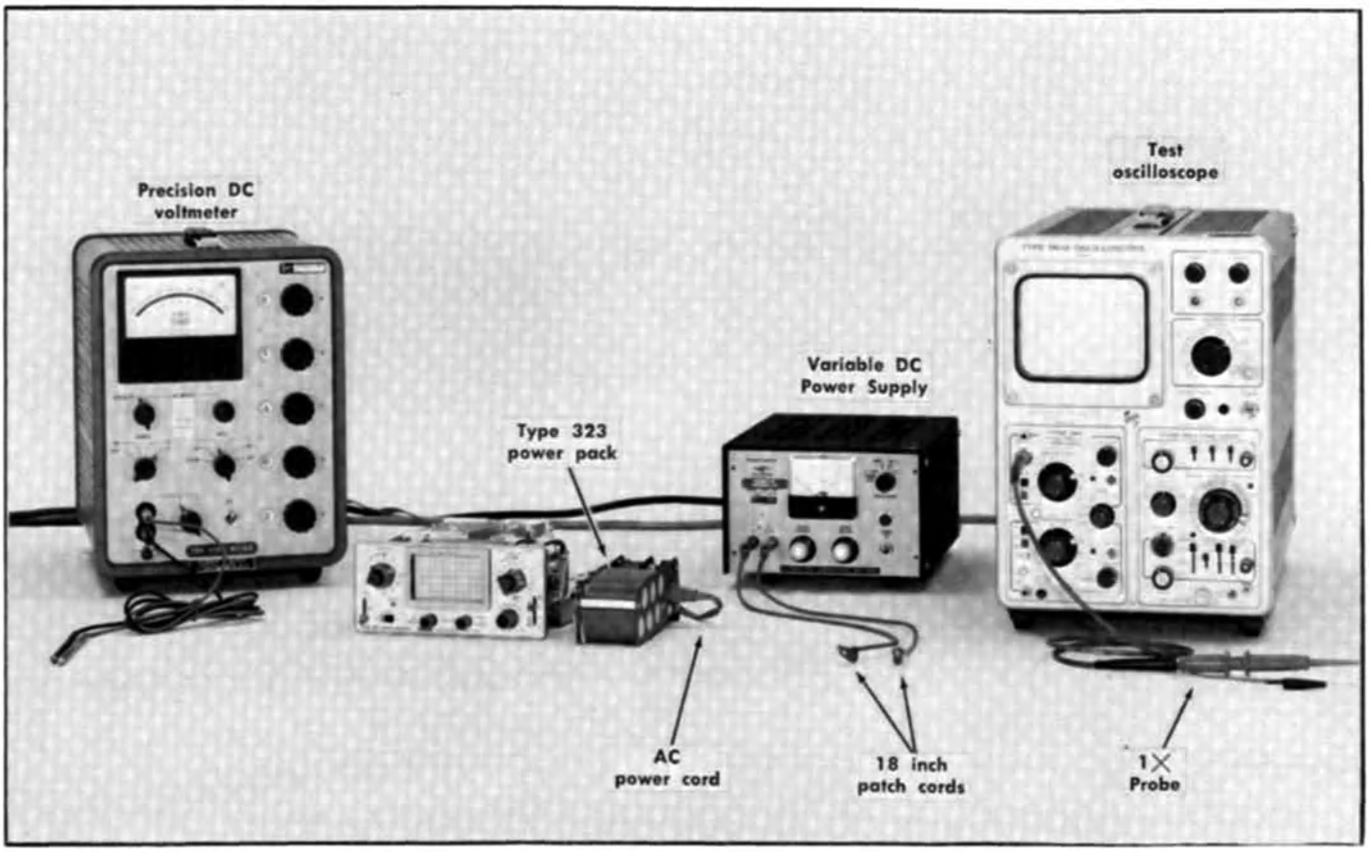


Fig. 6-1. Initial test equipment setup for steps 1 through 12.

Vertical Controls	
VOLTS/DIV	.01
VARIABLE	CAL
INPUT	GND
Vertical POSITION	Midrange
×10 VERT GAIN	Pushed in
Triggering Controls	
TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1×
Horizontal Controls	
TIME/DIV	1 ms
VARIABLE	CAL
Horizontal POSITION	Midrange
×10 HORIZ MAG	Pushed in
CRT Controls	
FOCUS	Midrange
INTENSITY	Fully counterclockwise

Power Controls	
POWER	ON
Power Pack (rear panel)	FULL CHG

1. Adjust Charging Current

a. Test equipment setup is shown in Fig. 6-1.

b. Connect the precision DC voltmeter across R615 (see Fig. 6-2). The positive lead of the voltmeter should be connected to the bottom of R615. Be sure the negative lead of the voltmeter is isolated from ground.

c. CHECK—Meter reading; 54 millivolts, ±3 millivolts (180 milliamps, ±10 milliamps).

d. ADJUST—Charge Rate adjustment, R644 (see Fig. 6-2), for a meter reading of 54 millivolts.

e. Set the Power Pack switch (rear panel of power pack) to TRICKLE CHG.

f. CHECK—Meter reading; approximately 20 millivolts.

g. Disconnect the precision DC voltmeter and the AC power cord.

Ⓐ

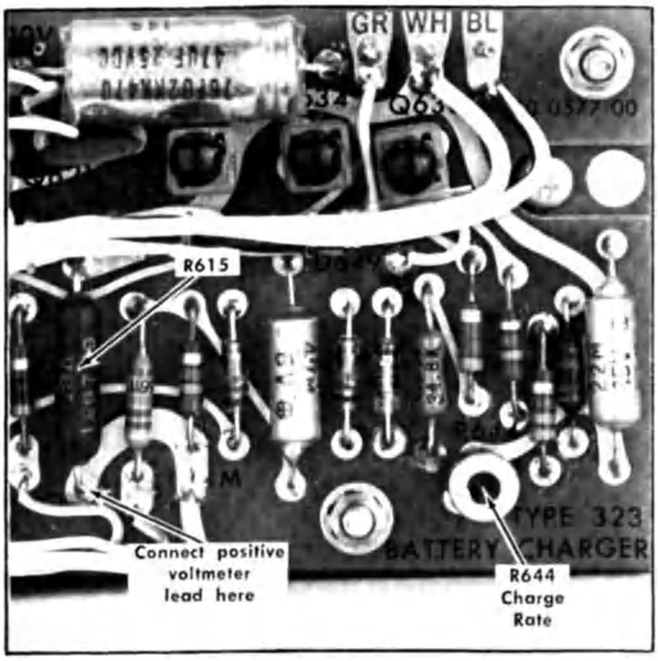


Fig. 6-2. Location of R615 and Charge Rate adjustment (Power Pack board).

2. Adjust High-Voltage Supply and Check Regulation

a. Set the Power Pack switch to EXT DC.

b. Install the power pack in the Type 323.

c. Connect the variable DC power supply to the EXT DC POWER input jacks with the banana-plug patch cords (be sure to observe correct polarity; red positive and black negative).

d. Set the variable DC power supply for a +8-volt output.

e. Connect the DC voltmeter (VOM)[2] from the high-voltage test point (point L or K, Power Supply board; see Fig. 6-3A) to chassis ground.

f. CHECK—Meter reading; —1900 volts, ±38 volts.

g. ADJUST—High voltage adjustment, R513 (Power Regulator board; see Fig. 6-3B), for a meter reading of —1900 volts.

h. Change the variable DC power supply output voltage between +6 volts and +16 volts. Also, set the INTENSITY control fully clockwise at +6 volts and fully counterclockwise at +16 volts.

i. CHECK—Less than ±38 volts change in the high-voltage output level.

NOTE

If the high-voltage supply is out of regulation, check the regulation of the low-voltage supplies (step 8) before troubleshooting in the high-voltage supply.

j. Return the variable DC power supply to +8 volts.

k. INTERACTION—May affect operation of all circuits within the Type 323.

[2] If the precision 2 kV voltage divider is available for use with the precision DC voltmeter, it should be used for this step.

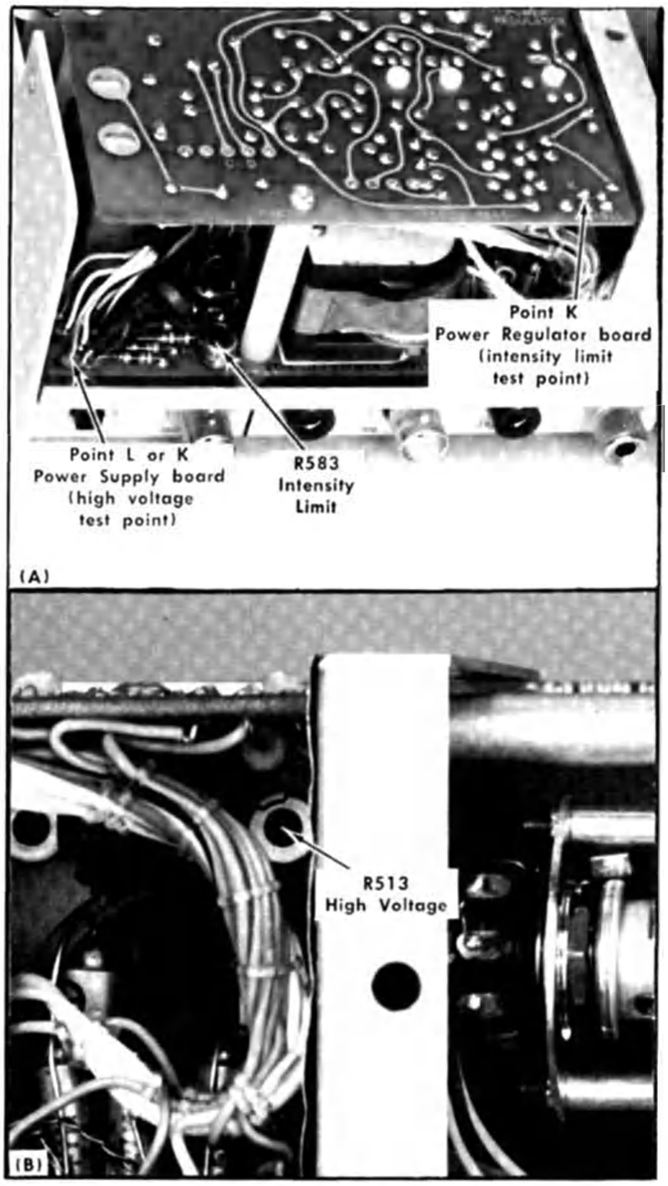


Fig. 6-3. Location of high-voltage test points and adjustments (Power Regulator and Power Supply boards).

3. Adjust Intensity Limit

a. Connect the precision DC voltmeter from the intensity limit test point (point K, Power Regulator board; see Fig. 6-3A) to chassis ground.

b. Set the INTENSITY control fully clockwise (maximum).

c. CHECK—Meter reading; 1.00 volts, ±0.05 volt (300 microamps, ±15 microamps). Take into account any meter loading of R572 if the recommended meter is not used.

d. ADJUST—Intensity Limit adjustment, R583 (Power Supply board; see Fig. 6-3A) for a meter reading of 1.00 volts. If R583 cannot be adjusted to obtain 1.00 V, R584 may have to be re-selected. If the Power Regulator board terminal k voltage is too low, replace R584 with a smaller value resistor (not less than 470 kΩ); if the voltage is too high, replace R584 with a larger value resistor (not more than 1.8 MΩ). Ideally, a value should be selected (within the prescribed range) which permits a near mid-range setting of R583.

4. Adjust +5-Volt Power Supply (CAL OUT Voltage)

a. Connect the precision DC voltmeter from the CAL OUT jack to chassis ground.

b. Remove Q9 from the Main board (see Fig. 6-4A).

c. CHECK—Meter reading; +0.500 volt, ±2.5 millivolts.

d. ADJUST— +5 Volts adjustment, R552 (see Fig. 6-4B), for a meter reading of +0.500 volts.

e. Disconnect the precision DC voltmeter and replace Q9.

f. Connect the precision DC voltmeter from the +5-volt test point (point R, Main board; see Fig. 6-4A) to chassis ground.

g. CHECK—Meter reading; +5.0 volts, ±0.1 volt.

h. INTERACTION—May affect operation of all circuits within the Type 323.

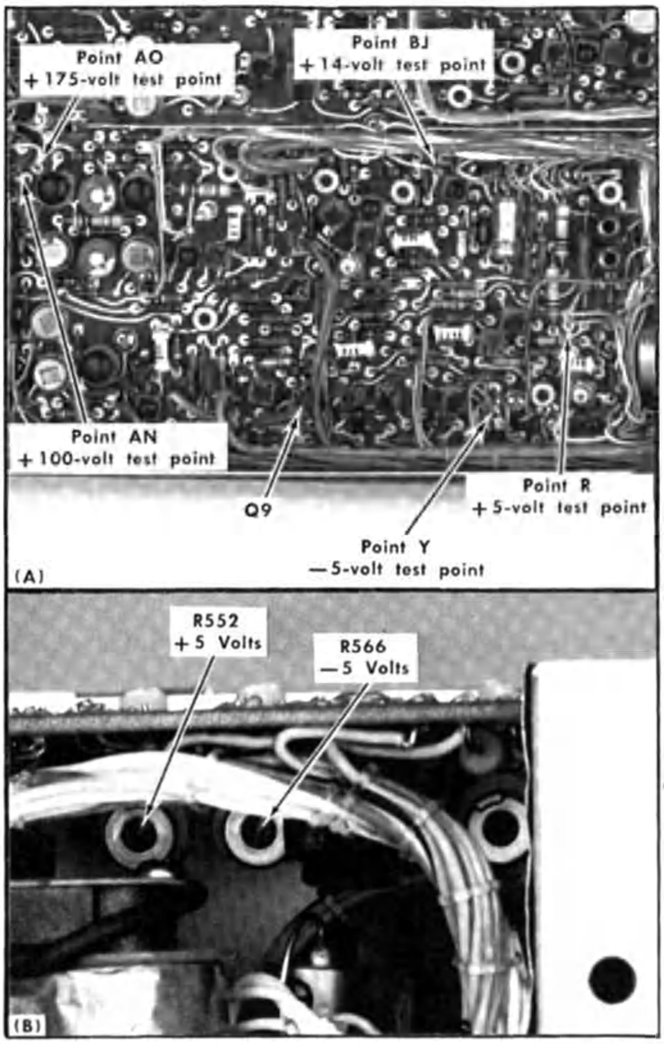


Fig. 6-4. (A) Location of Q9 and power-supply test points (Main board), (B) location of power-supply adjustments (Power Regulator board).

5. Adjust —5-Volt Power Supply

a. Connect the precision DC voltmeter from the —5-volt test point (point Y, Main board; see Fig. 6-4A) to chassis ground.

b. CHECK—Meter reading; —5 volts, ±0.1 volt.

c. ADJUST— —5 Volts adjustment, R566 (see Fig. 6-4B), for a meter reading of —5 volts.

d. INTERACTION—May affect operation of all circuits within the Type 323.

6. Check +14-Volt, +100-Volt and +175-Volt Power Supplies

a. Connect the precision DC voltmeter from the +14-volt test point (point BJ, Main board; see Fig. 6-4A) to chassis ground.

b. CHECK—Meter reading; +14 volts, ±2.8 volts.

c. Connect the precision DC voltmeter from the +100-volt test point (point AN, Main board; see Fig. 6-4A) to chassis ground.

d. CHECK—Meter reading; +100 volts, ±5 volts.

e. Connect the precision DC voltmeter from the +175-volt test point (point AO, Main board; see Fig. 6-4A) to chassis ground.

f. CHECK—Meter reading; +175 volts, within +14 and —7 volts.

g. Disconnect the precision DC voltmeter.

7. Check Low Voltage Power-Supply Ripple

a. Change the following control settings:

TIME/DIV	EXT HORIZ
Vertical POSITION	Position spot off screen

b. Connect the 1× probe to the test oscilloscope input.

c. Set the test oscilloscope for a vertical deflection factor of 0.01 volt/division, AC coupled, at a sweep rate of 20 microseconds/division.

d. CHECK—Test oscilloscope display for maximum ripple of each supply while varying the DC power supply output voltage between +6 volts and +16 volts. Table 6-1 lists the maximum ripple for each supply; Fig. 6-4A shows the power-supply test points. Change the vertical deflection factor of the test oscilloscope as necessary to make each measurement.

e. Disconnect the test oscilloscope.

8. Check Low-Voltage Power-Supply Regulation

a. Change the variable DC power supply output voltage between +6 volts and +16 volts. Also set the INTENSITY control fully clockwise at +6 volts and fully counterclockwise at +16 volts.

TABLE 6-1

Power-Supply Ripple and Regulation

Power Supply	Maximum Ripple	Maximum output change of supply (regulation)
−5-Volt	10 millivolts	±0.03 volt
+5-Volt	10 millivolts	±0.025 volt
+14-Volt	150 millivolts	±2.8 volts
+100-Volt	150 millivolts	±5.0 volts
+175-Volt	500 millivolts	±14 volts

b. CHECK—Precision DC voltmeter for power-supply output change within the limits given in Table 6-1 while varying the DC power source as given above. Power-supply test points are shown in Fig. 6-4A.

c. Disconnect the precision DC voltmeter.

d. Turn off the POWER switch temporarily and replace the high-voltage cover. Replacement instructions are given in the Maintenance section of this manual.

9. Check Low Batteries Indicator

a. Change the following control settings:

Vertical POSITION	Midrange
TIME/DIV	1 ms
INTENSITY	Normal intensity
POWER	ON

b. Slowly decrease the output voltage of the variable DC power supply.

c. CHECK—LOW BATT light begins to flash when variable DC power supply output voltage is +6.25 volts, ±0.31 volt (use the precision DC voltmeter to monitor the applied DC voltage at the EXT DC POWER jacks).

d. Return variable DC power supply output voltage to +8 volts.

NOTE

If the internal batteries of the Type 323 are charged, the remainder of this procedure can be performed with battery powered operation.

10. Adjust Variable Volts/Division Balance

a. Position the trace to the center horizontal line with the vertical POSITION control.

b. CHECK—Rotate the VARIABLE VOLTS/DIV control throughout its range. Trace should not move more than one division vertically (if the trace is not visible at all, preset the VAR V/DIV BAL adjustment to bring the trace on screen).

c. ADJUST—VAR V/DIV BAL adjustment, R40 (see Fig. 6-5), for no trace shift as the VARIABLE VOLTS/DIV control is rotated. If necessary, use the vertical POSITION control to keep the trace on screen during this adjustment.

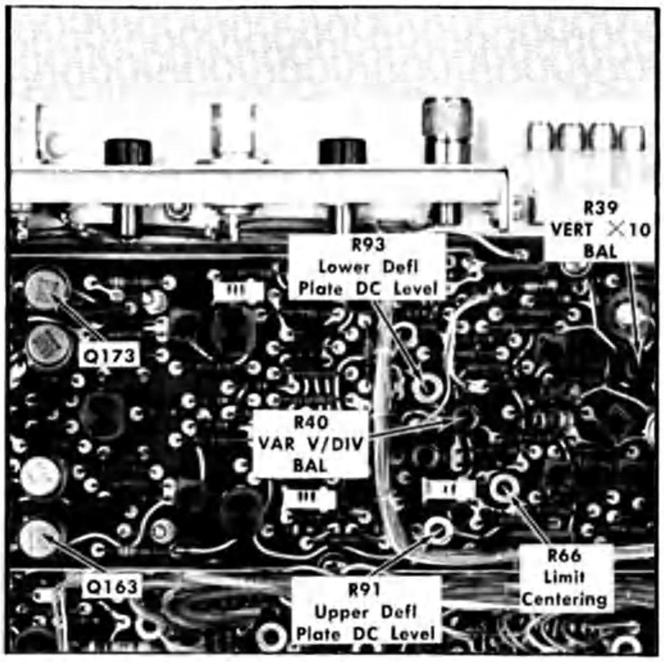


Fig. 6-5. Location of vertical adjustments (Main board).

11. Adjust Vertical ×10 Balance

a. Return the VARIABLE VOLTS/DIV control to CAL.

b. Position the trace to the center horizontal line with the vertical POSITION control.

c. Pull the ×10 VERT GAIN switch out. (Note: to prevent changing knob position, the ×10 VERT GAIN switch can be actuated using the vertical POSITION control bracket behind the front panel).

d. CHECK—Trace shift less than 1.5 division vertically.

e. ADJUST—VERT ×10 BAL adjustment, R39 (see Fig. 6-5), to return the trace to the center horizontal line. Repeat parts b through e for minimum trace shift as the ×10 VERT GAIN switch is pulled out.

f. Recheck step 10. If readjustment is necessary, recheck this step also.

12. Adjust Deflection Plate DC Level

a. Push the ×10 VERT GAIN switch in.

b. Connect the precision DC voltmeter from the collector of Q163 (case of Q163; see Fig. 6-5) to chassis ground.

c. Rotate the vertical POSITION control fully clockwise and note the meter reading. Then rotate the vertical POSITION control fully counterclockwise and again note the meter reading.

d. CHECK—Voltage range measured in part c centered around +50 volts.

e. ADJUST—Upper Defl Plate DC Level adjustment, R91 (see Fig. 6-5), to center the measured voltage range around +50 volts.

f. Connect the precision DC voltmeter from the collector of Q173 (case of Q173; see Fig. 6-5) to chassis ground.

g. Rotate the vertical POSITION control fully clockwise and note the meter reading. Then rotate the vertical POSITION control fully counterclockwise and again note the meter reading.

h. CHECK—Voltage range measured in part g centered around +50 volts.

i. ADJUST—Lower Defl Plate DC Level adjustment, R93 (see Fig. 6-5) to center the measured voltage range around +50 volts.

j. Position the trace to the center horizontal line with the vertical POSITION control.

k. Connect the precision DC voltmeter from the collector of Q163 (case of Q163; see Fig. 6-5) to chassis ground.

l. Preadjust the Limit Centering adjustment, R66 (see Fig. 6-5), for a meter reading of +50 volts (perform this adjustment only if proceeding to next step).

m. Disconnect all test equipment.

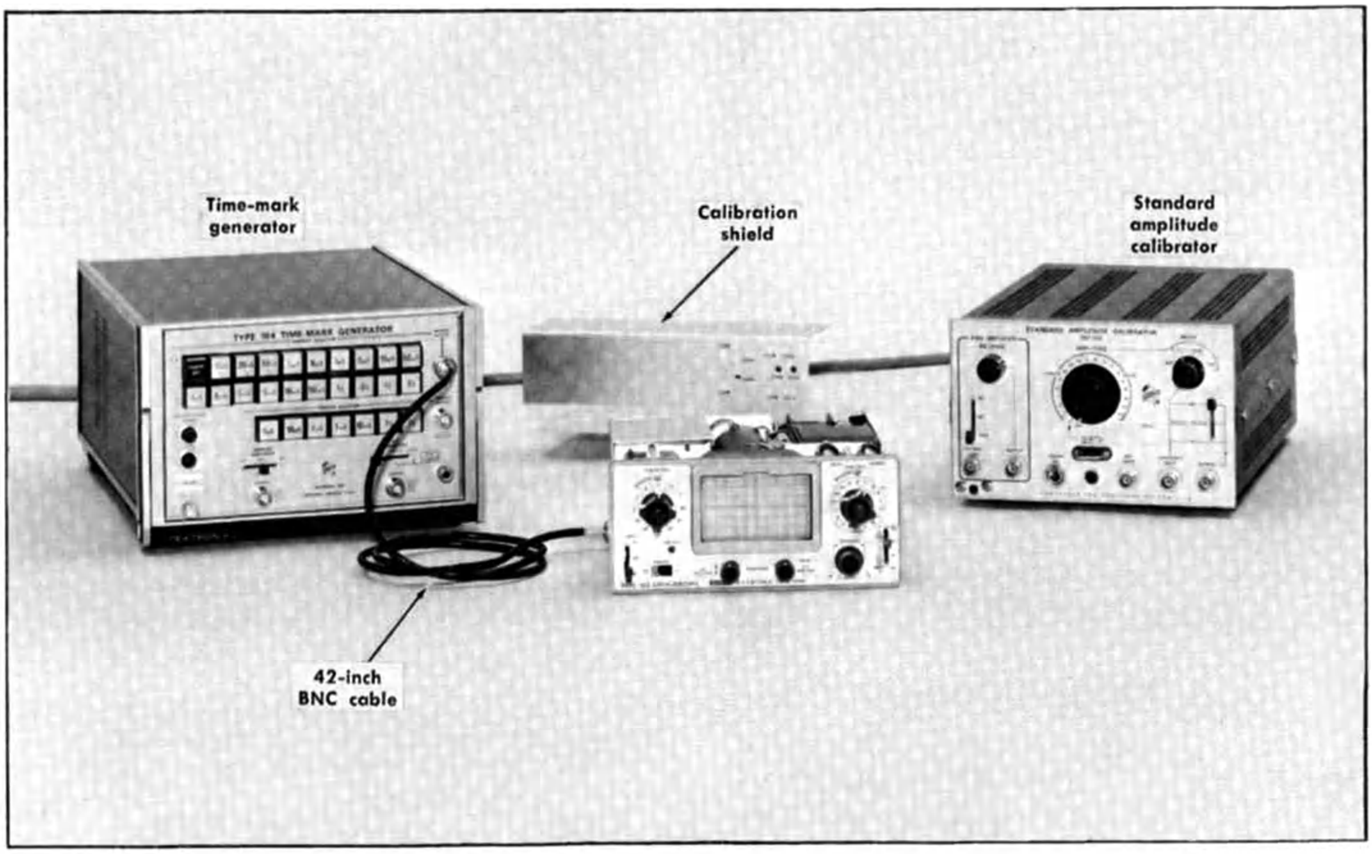


Fig. 6-6. Initial test equipment setup for steps 13 through 22.

Vertical Controls

VOLTS/DIV	**.5**
VARIABLE	CAL
INPUT	**DC**
Vertical POSITION	Midrange
×10 VERT GAIN	Pushed in

Triggering Controls

TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1×

Horizontal Controls

TIME/DIV	1 ms
VARIABLE	CAL
Horizontal POSITION	Midrange
×10 HORIZ MAG	Pushed in

CRT Controls

FOCUS	Midrange
INTENSITY	See procedure

Power Controls

POWER	ON
Power Pack (rear panel)	EXT DC

13. Adjust Astigmatism

a. Test equipment setup is shown in Fig. 6-6.

b. Set the INTENSITY control midway between a barely visible trace and fully clockwise.

c. Connect the time-mark generator (Type 184) to the VERT INPUT connector with the 42-inch BNC cable.

d. Set the time-mark generator for one-millisecond markers.

e. If necessary, set the TRIGGER control for a stable display.

f. CHECK—Markers should be well defined within the areas indicated in Fig. 6-7A with optimum setting of focus control.

g. ADJUST—FOCUS control and ASTIG adjustment, R597 (see Fig. 6-7B), for the best definition of the markers within the areas indicated in Fig. 6-7A.

14. Adjust Trace Alignment

a. Position the baseline of the marker display to the center horizontal line with the vertical POSITION control.

b. CHECK—Baseline of marker display should be parallel to the center horizontal line.

c. ADJUST—TRACE ROTATION adjustment, R592 (see Fig. 6-7B), so the baseline of the marker display is parallel to the center horizontal line.

15. Adjust CRT Geometry

a. Set the VOLTS/DIV switch to .1.

b. Position the baseline of the marker display below the bottom of the graticule with the vertical POSITION control.

c. CHECK—CRT display for curvature of vertical lines (markers) within maximum deviation of 0.1 division from straight line. Curvature can be most easily checked by positioning the markers to the vertical graticule lines with the horizontal POSITION control. Fig. 6-7C shows a typical display of good geometry.

d. ADJUST—Geom adjustment, R593 (see Fig. 6-7A), for minimum curvature of vertical lines.

e. Disconnect the time-mark generator.

f. Position the trace to the top line of the graticule with the vertical POSITION control.

g. CHECK—Deviation from straight line should not exceed 0.1 division.

h. Position the trace to the bottom line of the graticule with the vertical POSITION control.

i. CHECK—Deviation from straight line should not exceed 0.1 division.

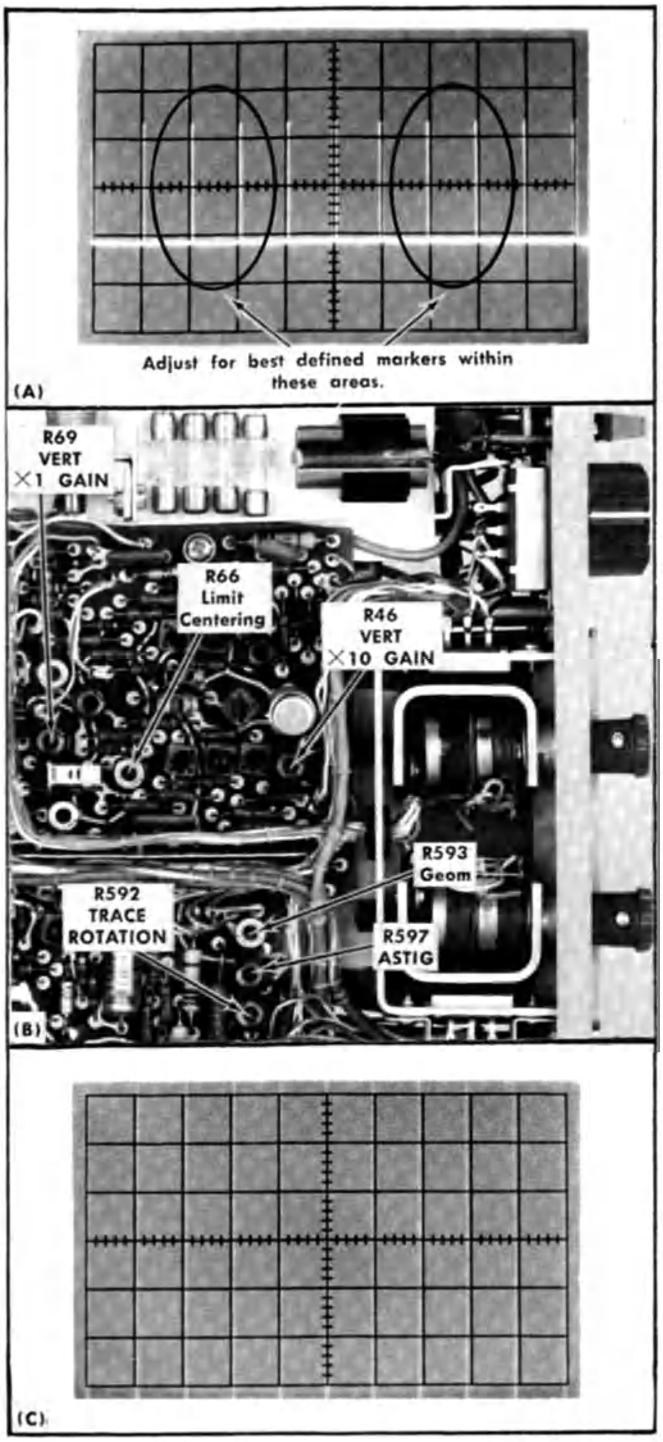


Fig. 6-7. (A) Typical CRT display when adjusting astigmatism, (B) location of adjustments (main board), (C) typical CRT display showing good geometry.

NOTE

It may be necessary to compromise the setting of the Geom adjustment to provide acceptable displays both in part c and parts g and i.

16. Adjust Limit Centering

a. Set the VOLTS/DIV switch to 5 DIV CAL.

b. Position the bottom of the display to the first graticule line below the center horizontal line.

c. Reduce the display to exactly two divisions with the VARIABLE VOLTS/DIV control.

d. Position the top of the display to the top horizontal line of the graticule. Note the compression (reduction in amplitude) of the display.

e. Position the bottom of the display to the bottom horizontal line of the graticule. Again note the compression of the display.

f. Return the display to the position which produces the most compression of the display.

g. ADJUST—Limit Centering adjustment, R66 (see Fig. 6-7B), for maximum display amplitude (least compression). Compression or expansion should not exceed 0.1 division.

17. Adjust Vertical ×1 Gain

a. Change the following control settings:

VOLTS/DIV	.01
VARIABLE VOLTS/DIV	CAL

b. Connect the standard amplitude calibrator (067-0502-00) output connector to the VERT INPUT connector with the 42-inch BNC cable.

c. Set the standard amplitude calibrator for a 50-millivolt square-wave output.

d. Center the display about the center horizontal line with the vertical POSITION control.

e. CHECK—CRT display for five divisions of deflection.

f. ADJUST—VERT ×1 GAIN adjustment, R69 (see Fig. 6-7B), for exactly five divisions of deflection.

18. Adjust Vertical ×10 Gain

a. Set the standard amplitude calibrator for a five-millivolt square-wave output.

b. Pull the ×10 VERT GAIN switch.

c. Center the display about the center horizontal line with the vertical POSITION control.

d. CHECK—CRT display for five divisions of deflection.

e. ADJUST—VERT ×10 GAIN adjustment, R46 (see Fig. 6-7B), for exactly five divisions of deflection.

19. Check Vertical Deflection Accuracy

a. Push the ×10 VERT GAIN switch in.

b. CHECK—Using the VOLTS/DIV switch and standard amplitude calibrator settings given in Table 6-2, check vertical deflection within 3% in each position of the VOLTS/DIV switch.

TABLE 6-2

Vertical Deflection Accuracy

VOLTS/DIV switch setting	Standard amplitude calibrator output	Vertical deflection in divisions	Maximum error for ±3% accuracy (divisions)
.01	50 millivolts	5	Previously set exactly in step 17
.02	0.1 volt	5	±0.15
.05	0.2 volt	4	±0.12
.1	0.5 volt	5	±0.15
.2	1 volt	5	±0.15
.5	2 volts	4	±0.12
1	5 volts	5	±0.15
2	10 volts	5	±0.15
5	20 volts	4	±0.12
10	50 volts	5	±0.15
20	100 volts	5	±0.15

20. Check Variable Volts/Division Control Range

a. Set the standard amplitude calibrator for a 50-millivolt square-wave output.

b. Change the following control settings:

VOLTS/DIV	.01
INPUT	AC

c. Center the display about the center horizontal line with the vertical POSITION control.

d. CHECK—Rotate the VARIABLE VOLTS/DIV control fully counterclockwise. Display must be reduced to two divisions or less (indicates adequate range for continuously variable deflection factor between the calibrated steps).

21. Check Input Coupling Switch Operation

a. Set the VARIABLE VOLTS/DIV control to CAL.

b. Set the standard amplitude calibrator for a 20-millivolt square-wave output.

c. Center the display about the center horizontal line with the vertical POSITION control.

d. Set the INPUT switch to GND.

e. CHECK—CRT display for straight line near the center horizontal line.

f. Set the INPUT switch to DC.

g. CHECK—CRT display for square wave with the bottom near the center horizontal line.

h. Disconnect all test equipment.

22. Check Trace Shift Due to Input Current

a. Change the following control settings:

INPUT	GND
×10 VERT GAIN	Pulled out

b. Install the calibration shield (067-0571-00) on the Type 323.

c. Position the trace to the center horizontal line with the vertical POSITION control.

d. CHECK—Set the INPUT switch to DC. Trace shift should be negligible (0.085 division maximum).

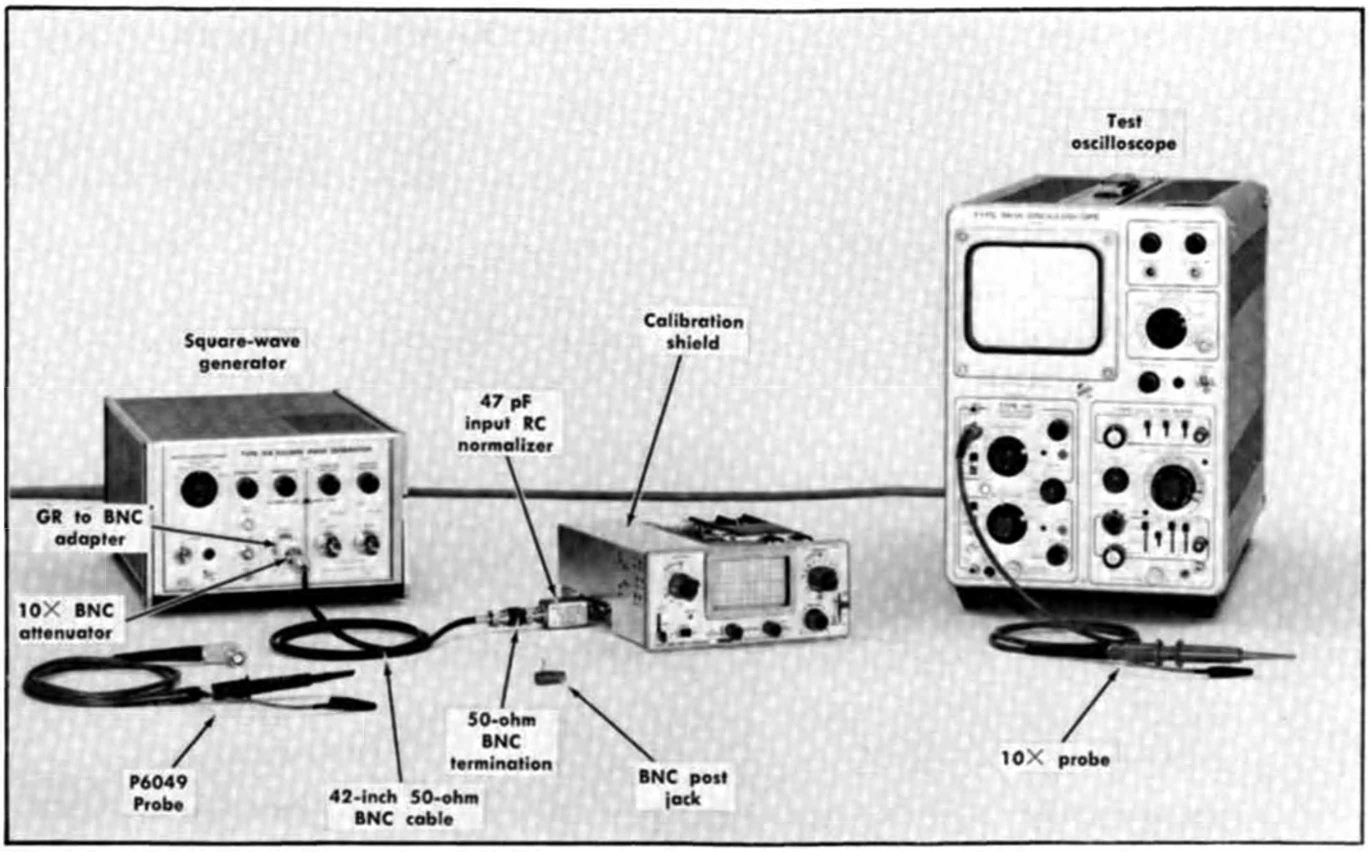


Fig. 6-8. Initial test equipment setup for steps 23 through 27.

Vertical Controls	
VOLTS/DIV	.01
VARIABLE	CAL
INPUT	DC
Vertical POSITION	Midrange
×10 VERT GAIN	**Pushed in**
Triggering Controls	
TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1×
Horizontal Controls	
TIME/DIV	**.5 ms**
VARIABLE	CAL
Horizontal POSITION	MIDRANGE
×10 HORIZ MAG	Pushed in
CRT Controls	
FOCUS	Adjust for focused display
INTENSITY	Adjust for visible display
Power Controls	
POWER	ON
Power Pack (rear panel)	EXT DC

23. Check Input Capacitance

a. Test equipment setup is shown in Fig. 6-8.

b. The calibration shield should be on the Type 323 (installed in previous step).

c. Connect the square-wave generator (Type 106) high-amplitude output connector to the VERT INPUT connector through the GR to BNC adapter, 10× BNC attenuator, 42-inch 50-ohm BNC cable, 50-ohm BNC termination and 47 pF input RC normalizer, in given order.

d. Set the square-wave generator for a five-division display at one kilohertz.

e. CHECK—CRT display for 0.2 division, or less, overshoot or rounding (47 pF, ±4 pF; see Fig. 6-9.

f. Disconnect all test equipment (leave calibration shield on).

24. Adjust Volts/Division Switch Compensation

a. Connect the P6049 Probe to the VERT INPUT connector.

b. Install the GR to BNC adapter, 10× BNC attenuator and BNC post jack on the square-wave generator high-amplitude output connector in given order.

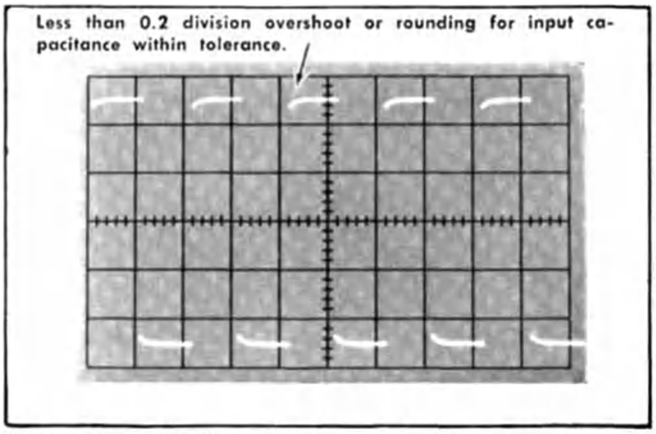


Fig. 6-9. Typical CRT display when checking input capacitance.

c. Connect the probe tip to the BNC post jack.

d. Set the square-wave generator for a five-division display at one kilohertz.

e. Compensate the probe as described in the probe instruction manual.

f. CHECK—CRT display at each VOLTS/DIV switch setting for optimum square corner and flat top within +3% or —3%, or total peak-to-peak aberrations not to exceed 3%. Readjust the generator at each setting, remove the attenuator and pull the ×10 VERT GAIN switch as given in Table 6-3 to maintain a five-division display.

g. ADJUST—VOLTS/DIV switch compensation as given in Table 6-3. First adjust for optimum square corner on the display and then for optimum flat top. Readjust the generator output with each setting of the VOLTS/DIV switch, remove the attenuator and pull the ×10 VERT GAIN switch as given in Table 6-3 to provide five divisions of deflection. Fig. 6-10B shows the location of the variable capacitors.

h. Disconnect all test equipment and remove the calibration shield.

25. Adjust Internal Trigger Compensation

a. Change the following control settings:

VOLTS/DIV	.5
×10 VERT GAIN	Pushed in

b. Connect the square-wave generator high-amplitude output connector to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable and 50-ohm BNC termination.

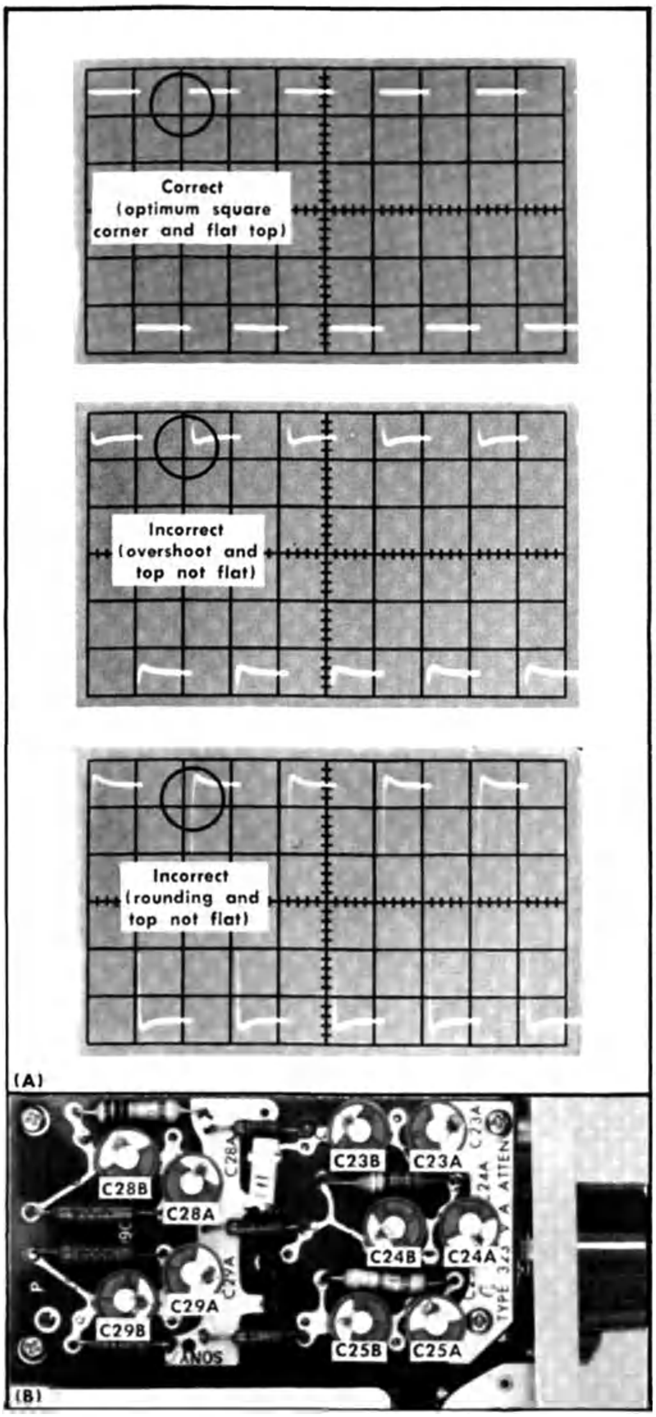


Fig. 6-10. (A) Typical CRT display showing correct and incorrect compensation, (B) location of compensation adjustments (Attenuator board).

c. Connect the 10× probe to the input connector of the test oscilloscope.

d. Set the test oscilloscope for a vertical deflection factor of 20 millivolts/division (0.2 volts/division at 10× probe tip) at a sweep rate of 0.5 milliseconds/division. Adjust the triggering controls when necessary to provide a stable display.

TABLE 6-3

VOLTS/DIV Compensation

VOLTS/DIV switch setting	Attenuator compensated	Adjust for optimum Square Corner	Adjust for optimum Flat Top
.01	÷ 1	Compensate P6049 Probe	
.02	÷ 2	C28B	C28A
.05	÷ 5	C29B	C29A
Remove external 10× attenuator from generator			
.1	÷ 10	C23B	C23A
.2	Check	If out of tolerance, compromise setting at .1 and .2 for best overall response	
.5	Check	If out of tolerance, compromise setting at .1, .2 and .5 for best overall response	
1	÷ 100	C24B	C24A
2	Check	If out of tolerance, compromise setting at 1 and 2 for best overall response	
Pull ×10 VERT GAIN switch			
5	Check	If out of tolerance, compromise setting at 1, 2 and 5 for best overall response	
10	÷ 1000	C25B	C25A
20	Check	If out of tolerance, compromise setting at 10 and 20 for best overall response	

e. Connect the 10× probe tip to the trigger compensation test point (point T, Main board; see Fig. 6-11C). Be sure the probe is compensated.

f. Set the square-wave generator for a one kHz-five-division vertical display on the test oscilloscope. Disregard overshoot or rounding and adjust for five divisions as measured between trailing edges of square waves. See Fig. 6-11(A).

g. CHECK—Test oscilloscope display for about one-division front-corner rounding at normal CRT intensity, similar to Fig. 6-11A. An undercompensated waveform is shown in Fig. 6-11(B).

h. ADJUST—C201 (see Fig. 6-11C) for about one-division front-corner rounding as shown in Fig. 6-11A. More rounding may reduce triggering circuit frequency response and less rounding may produce unstable triggering.

26. Adjust External Trigger Compensation

a. Change the following control settings:

Trig/Horiz Coupling	EXT TRIG DC
EXT TRIG OR HORIZ ATTEN (side panel)	10×

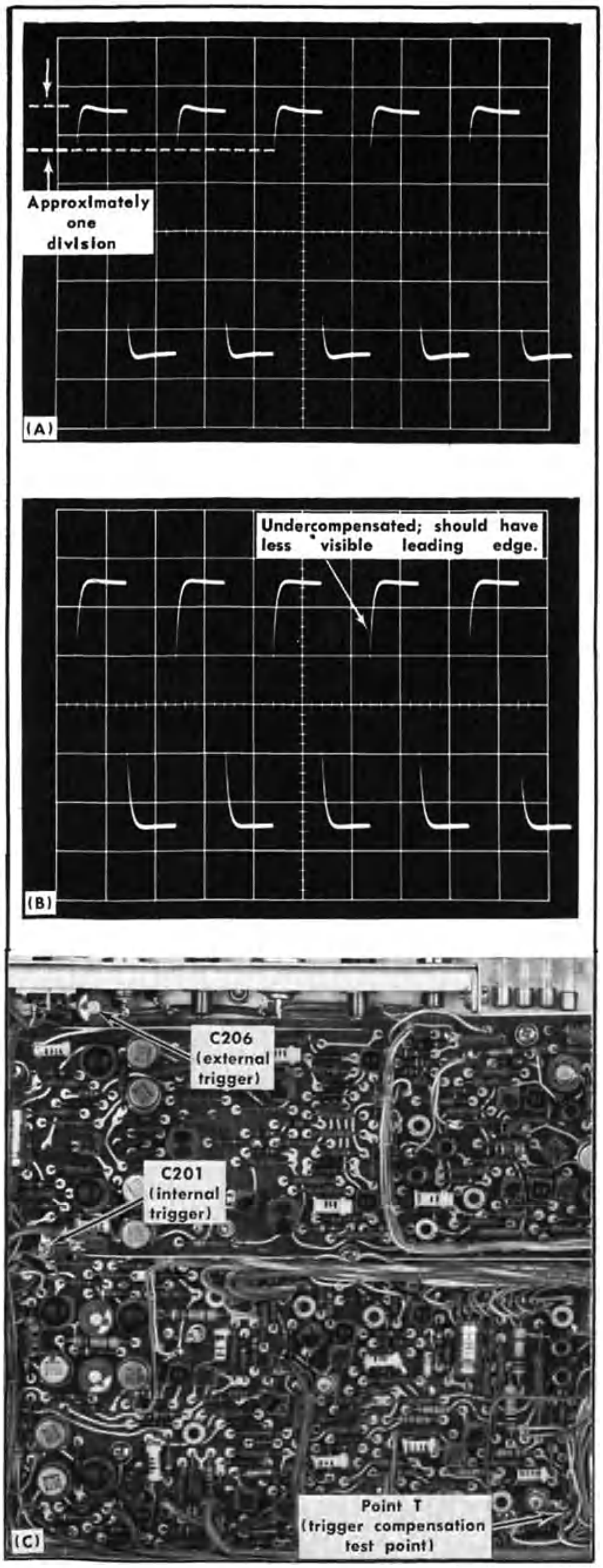


Fig. 6-11. (A) Typical test oscilloscope display showing correct internal trigger compensation, (B) undercompensated waveform, (C) location of trigger compensation test point and adjustments (Main board).

b. Disconnect the output of the BNC termination from the VERT INPUT connector and reconnect it to the EXT TRIG OR HORIZ INPUT connector.

c. Set the square-wave generator for a five-division display on the test oscilloscope at one kilohertz.

d. CHECK—Test oscilloscope display for optimum square-wave response (optimum square corner and flat top).

e. ADJUST—C206 (see Fig. 6-11C) for optimum square-wave response.

f. Disconnect all test equipment.

27. Adjust High-Frequency Compensation

a. Change the following control settings:

VOLTS/DIV	.01
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	5 μs
×10 HORIZ MAG	Pulled out

b. Connect the square-wave generator fast-rise + output connector to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 10× BNC attenuator and the 50-ohm BNC termination.

c. Set the square-wave generator for a four-division display at 100 kilohertz.

d. Move the leading edge of the square wave onto the viewing area with the horizontal POSITION control.

e. Set the test oscilloscope for a vertical deflection factor of one volt/division (10 volts/division at 10× probe tip) at a sweep rate of two microseconds/division. Adjust the triggering controls when necessary to provide a stable display.

f. Connect the 10× probe tip to the collector of Q163 (case of Q163; see Fig. 6-12B). Be sure the probe is compensated.

g. CHECK—Test oscilloscope display for flat top on square wave similar to Fig. 6-12A.

h. ADJUST—C160 (see Fig. 6-12B) for optimum flat top on square wave.

i. Connect the 10× probe tip to the collector of Q173 (case of Q173; see Fig. 6-12B).

j. CHECK—Test oscilloscope display for flat bottom on square wave similar to Fig. 6-12A.

k. ADJUST—C170 (see Fig. 6-12B) for optimum flat bottom on square wave.

l. Install the calibration shield on the Type 323.

m. CHECK—Type 323 CRT display for optimum square corner similar to Fig. 6-12C.

n. ADJUST—C160 and C170 about the same amount in the same direction for optimum square corner on the CRT display.

o. Disconnect all test equipment and remove the calibration shield.

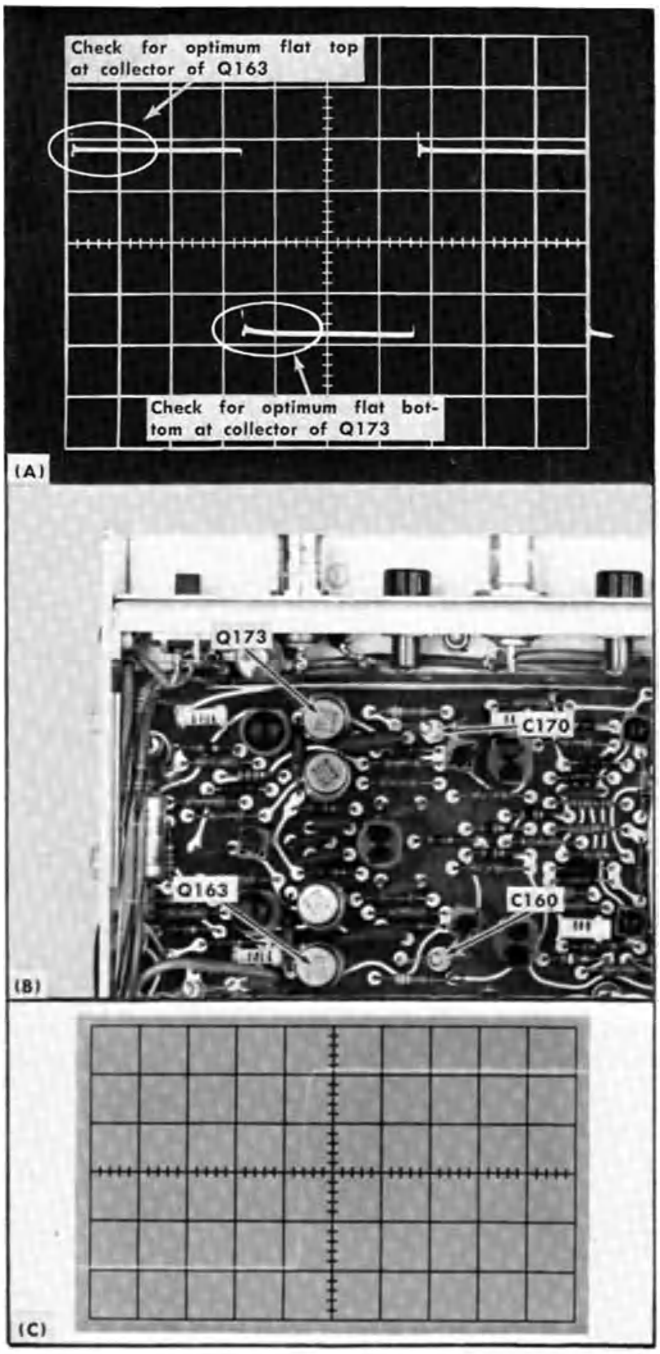


Fig. 6-12. (A) Typical oscilloscope display when adjusting high-frequency compensation, (B) location of high-frequency compensation test points and adjustments (Main board), (C) typical CRT display showing correct high-frequency compensation.

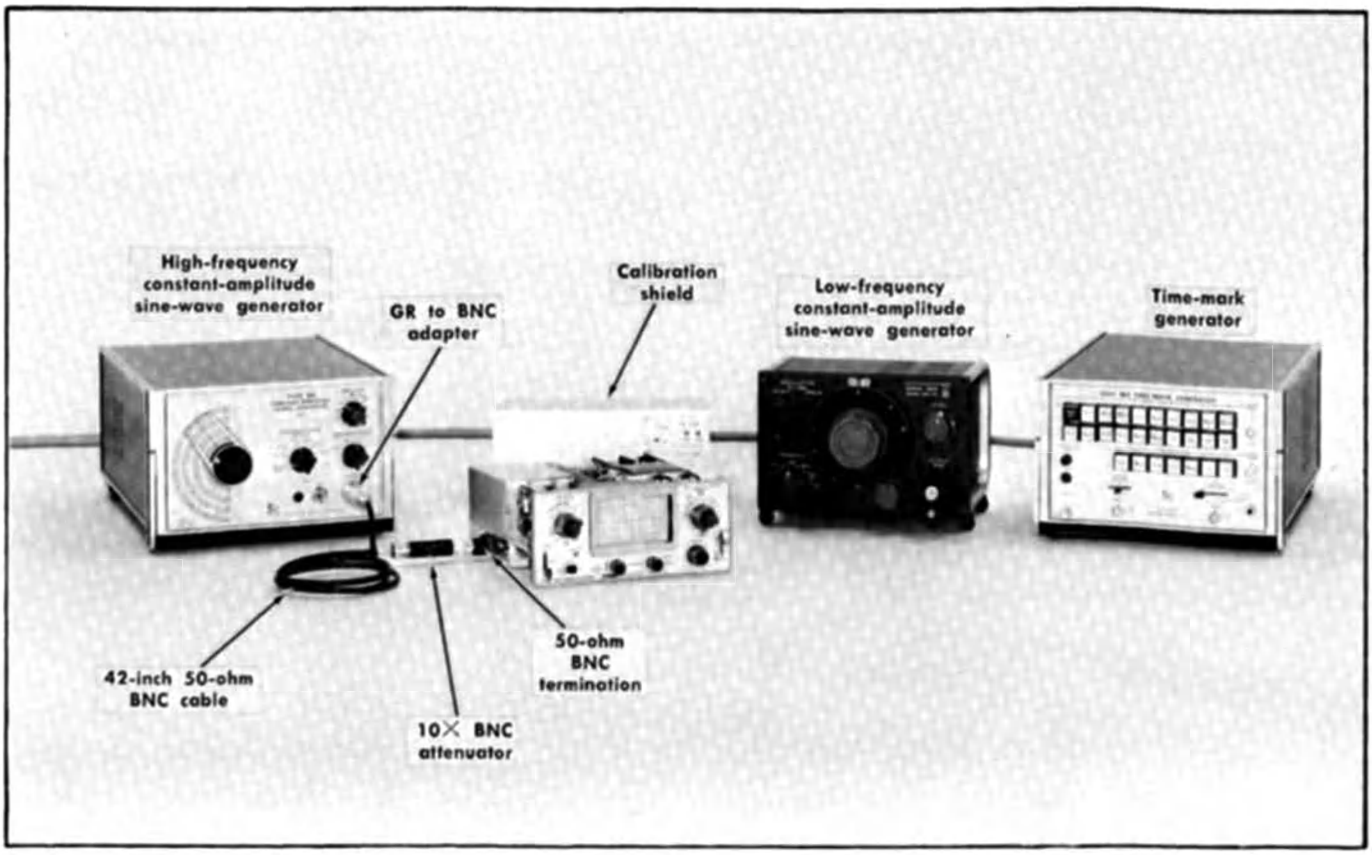


Fig. 6-13. Initial test equipment setup for steps 28 through 38.

Vertical Controls	
VOLTS/DIV	.01
VARIABLE	CAL
INPUT	DC
Vertical POSITION	Midrange
×10 VERT GAIN	Pushed In
Triggering Controls	
TRIGGER	+ Auto
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	10×
Horizontal Controls	
TIME/DIV	**1 ms**
VARIABLE	CAL
Horizontal POSITION	Midrange
×10 HORIZ MAG	**Pushed in**
CRT Controls	
FOCUS	Adjust for focused display
INTENSITY	Adjust for visible display
Power Controls	
POWER	ON
Power Pack (rear panel)	EXT DC

28. Check Upper Vertical Bandwidth Limit

a. Test equipment setup is shown in Fig. 6-13.

b. Connect the high-frequency constant-amplitude sine-wave generator (Type 191) to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 10× BNC attenuator and the 50-ohm BNC termination.

c. Set the constant-amplitude generator for a four-division display, centered about the center horizontal line, at its reference frequency (50 kilohertz).

d. Without changing the output amplitude, increase the output frequency of the generator until the display is reduced to 2.8 divisions (—3 dB point).

e. CHECK—Output frequency of generator must be four megahertz or higher.

29. Check ×10 Vertical Gain Upper Bandwidth Limit

a. Pull the ×10 VERT GAIN switch out.

b. Set the constant-amplitude generator for a four-division display, centered about the center horizontal line, at its reference frequency (50 kilohertz).

c. Without changing the output amplitude, increase the output frequency of the generator until the display is reduced to 2.8 divisions (—3 dB point).

d. CHECK—Output frequency of generator must be 2.75 megahertz or higher.

e. Disconnect all test equipment.

30. Check AC-Coupled Lower Vertical Bandwidth Limit

a. Connect the low-frequency constant-amplitude generator to the VERT INPUT connector through the 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

b. Change the following control settings:

INPUT	AC
×10 VERT GAIN	Pushed in
TIME/DIV	.5 s

c. Set the low-frequency generator for a four-division display, centered about the center horizontal line at a reference frequency of one kilohertz.

d. Without changing the output amplitude, reduce the output frequency of the generator to two hertz.

e. CHECK—CRT display 2.8 divisions, or greater, in amplitude (not more than —3 dB).

f. Disconnect all test equipment.

31. Adjust Magnified Registration

a. Change the following control settings:

VOLTS/DIV	.5
INPUT	DC
TIME/DIV	1 ms

b. Connect the time-mark generator to the VERT INPUT connector through a 42-inch 50-ohm BNC cable and a 50-ohm BNC termination.

c. Set the time-mark generator for five-millisecond markers.

d. Set the TRIGGER control for a stable display in the variable positive-slope area.

e. Position the middle marker (three markers on sweep) to the center vertical line (see Fig. 6-14A).

f. Pull the 10× HORIZ MAG switch out (Note: to prevent changing knob position, the ×10 HORIZ MAG switch can be actuated using the horizontal POSITION control bracket behind the front panel).

g. CHECK—Middle marker should be within one division of the center vertical line (see Fig. 6-14B).

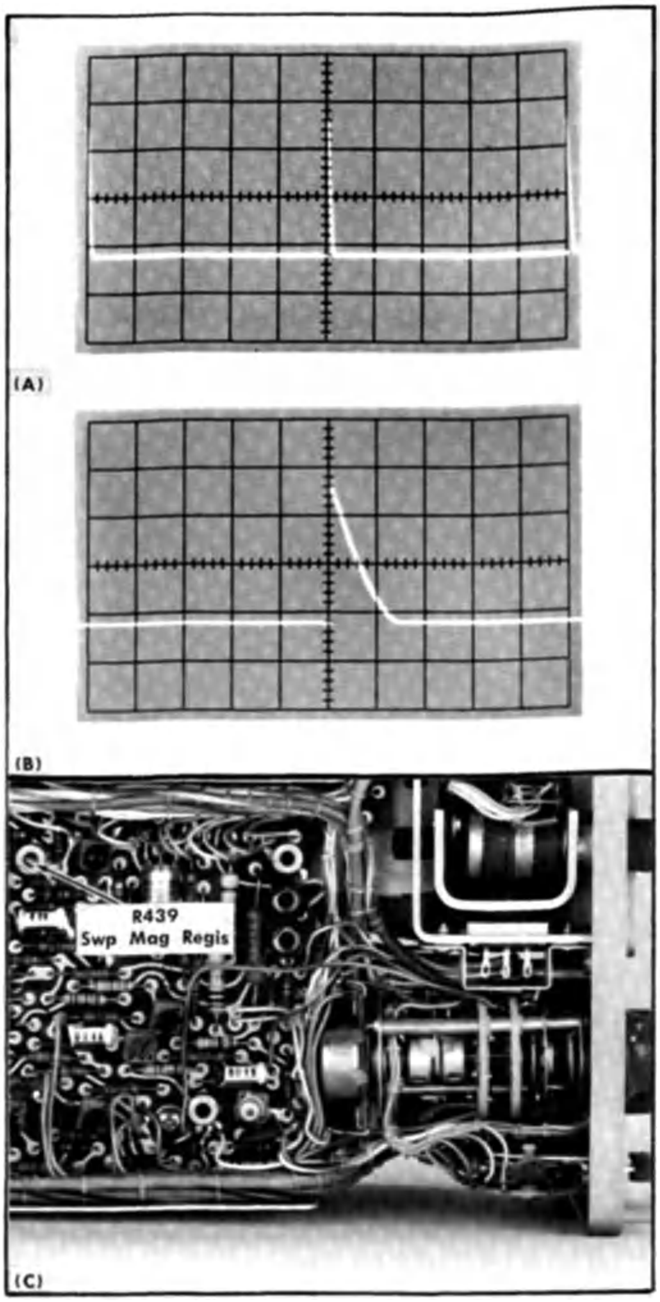


Fig. 6-14. Typical CRT displays showing correct magnified registration; (A) ×10 HORIZ MAG switch pushed in, (B) ×10 HORIZ MAG switch pulled out. (C) Location of magnifier registration adjustment (Main board).

h. ADJUST—Swp Mag Regis adjustment, R439 (see Fig. 6-14C), to position the middle marker to the center vertical line.

i. INTERACTION—Check step 35.

32. Adjust Normal Timing

a. Change the following control settings:

TRIGGER	+ AUTO
×10 HORIZ MAG	Pushed in

b. Set the time-mark generator for one-millisecond markers.

c. CHECK—CRT display for one marker each division between the second- and tenth-vertical lines of the graticule (see Fig. 6-15A). Tenth marker must be within 0.24 division (within 3%) of the tenth vertical line with the second marker positioned exactly to the second vertical line.

NOTE

Unless otherwise noted, use the middle eight horizontal divisions (between second and tenth vertical lines of the graticule) when checking or adjusting timing.

d. ADJUST—×1 Gain, R401 (see Fig. 6-15B), for one marker each division. The second and tenth markers must coincide exactly with their respective graticule lines (reposition the display slightly with the horizontal POSITION control if necessary).

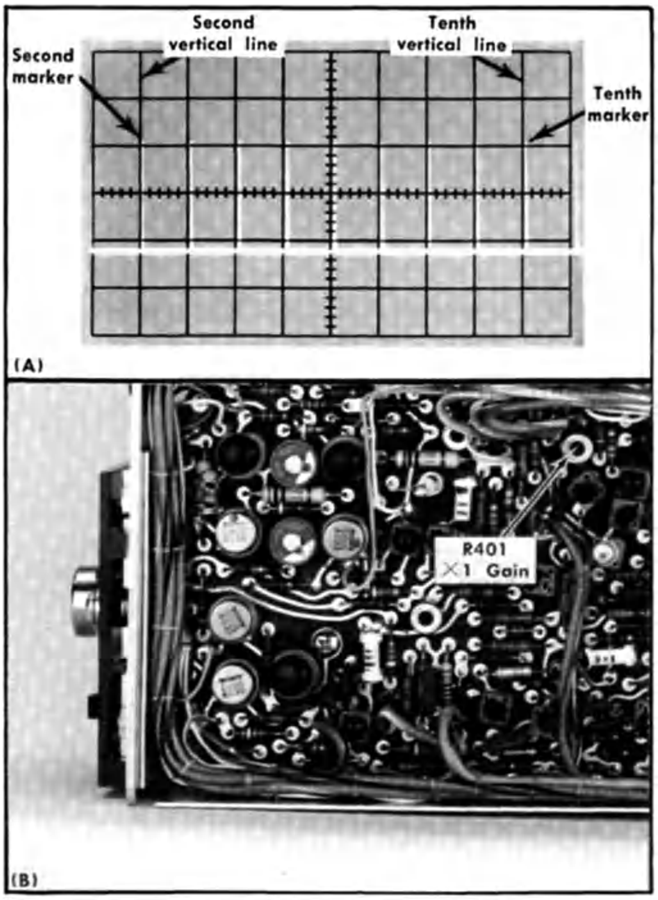


Fig. 6-15. (A) Typical CRT display showing correct normal timing, (B) location of normal timing adjustment (Main board).

e. INTERACTION—Check steps 33 through 38.

33. Check Variable Time/Division Control Range

a. Set the time-mark generator for 10-millisecond markers.

b. Set the TRIGGER control for a stable display in the variable positive-slope area.

c. Position the markers to the far left and right vertical lines of the graticule with the horizontal POSITION control.

d. Turn the VARIABLE TIME/DIV control fully counterclockwise.

e. CHECK—CRT display for four-division maximum spacing between markers (indicates adequate range for continuously variable sweep rates between the calibrated steps).

34. Adjust Sweep Length

a. Return the VARIABLE TIME/DIV control to CAL.

b. Set the time-mark generator for one-millisecond markers.

c. Adjust the TRIGGER control for a stable display in the variable positive-slope area.

d. Move the eleventh marker (only part of first marker may be visible) to the tenth vertical line with the horizontal POSITION control (see Fig. 6-16A).

e. CHECK—Sweep length between 10.5 and 11 divisions as shown by 0.5 to one division of display to the right of the tenth vertical line (see Fig. 6-16A).

f. ADJUST—Sweep Length adjustment, R347 (see Fig. 6-16B), for a sweep length of 10.7 divisions (0.7 division of display to the right of the tenth vertical line).

35. Adjust Magnified Timing

a. Set the time-mark generator for 0.1-millisecond markers.

b. Change the following control settings:

TRIGGER	Stable positive-slope triggering
Horizontal POSITION	Midrange
X10 HORIZ MAG	Pulled out

c. CHECK—CRT display for one marker each division between the second and tenth vertical lines. Marker at the tenth vertical line must be within 0.32 division (within 4%) of that graticule line when the marker at the second vertical line is positioned exactly.

d. ADJUST—×10 Gain adjustment, R433 (see Fig. 6-16B), for one marker each division. The second and tenth markers must coincide exactly with their respective graticule lines (reposition the display slightly with the horizontal POSITION control if necessary).

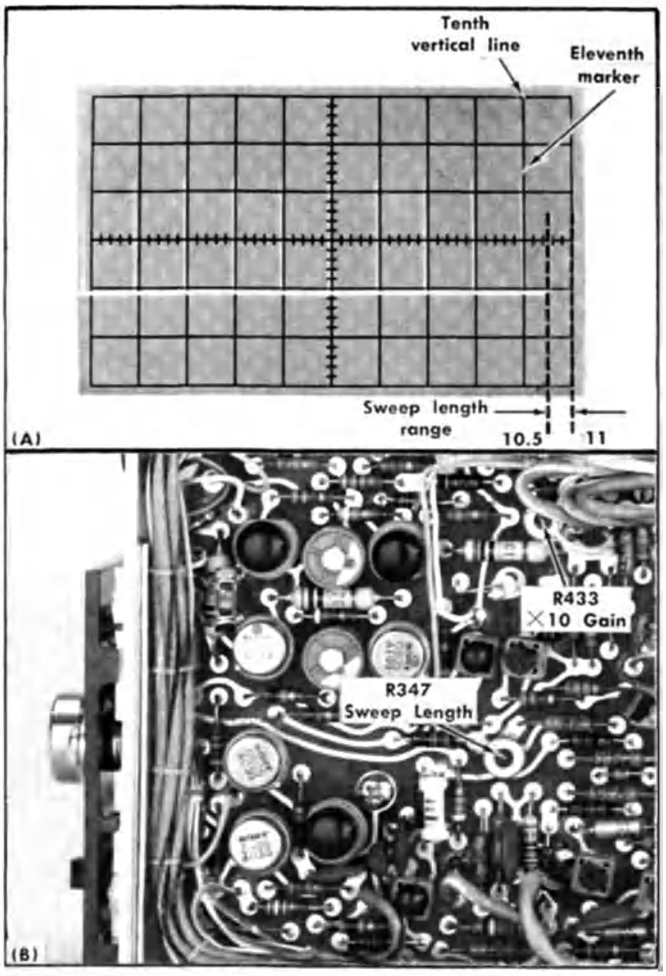


Fig. 6-16. (A) Typical CRT display when checking sweep length, (B) location of sweep length and magnified timing adjustments (Main board).

e. Position the first ten-division portion of the total magnified sweep onto the viewing area with the horizontal POSITION control.

f. CHECK—One marker each division between the second and tenth vertical lines. Marker at tenth vertical line must be within 0.32 division (within 4%) of that line when the marker at the second vertical line is positioned exactly.

g. Repeat this check for each ten division portion of the total magnified sweep length.

h. INTERACTION—Check steps 36 and 38.

36. Adjust High-Speed Timing

a. Install the calibration shield on the Type 323.

b. Set the TIME/DIV switch to 10 μs (×10 HORIZ MAG switch remains pulled out).

c. Set the horizontal POSITION control to midrange.

d. Set the time-mark generator for one-microsecond markers.

e. Set the TRIGGER control for a stable display.

f. CHECK—CRT display for optimum linearity and timing between the sixth and tenth vertical lines (see Fig. 6-17A).

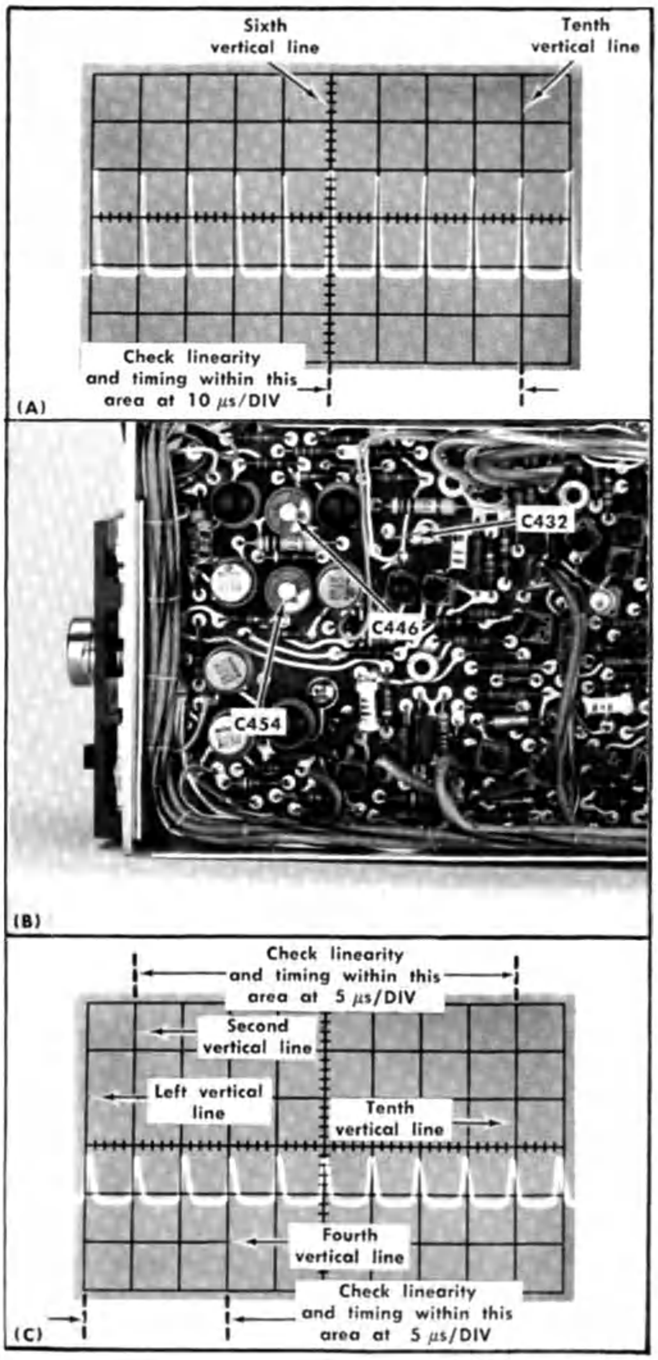


Fig. 6-17. (A) Typical CRT display showing correct high-speed linearity and timing at 10 μs/DIV, (B) location of high-speed timing adjustments (Main board), (C) typical CRT display showing correct high-speed linearity and timing at 5 μs/DIV.

g. ADJUST—C446 (see Fig. 6-17B) for optimum linearity and timing between the sixth and tenth vertical lines.

h. Set the time-mark generator for 0.5-microsecond markers.

i. Set the TIME/DIV switch to 5 μs.

j. Set the TRIGGER control for a stable display.

k. CHECK—CRT display for optimum linearity and timing between the second and tenth vertical lines (see Fig. 6-17C).

l. ADJUST—C454 (see Fig. 6-17B) for optimum linearity and timing between the second and tenth vertical lines.

m. CHECK—CRT display for optimum linearity and timing between the left (first) vertical line of the graticule and the fourth vertical line (see Fig. 6-17C).

n. ADJUST—C432 (see Fig. 6-17B) for optimum linearity and timing between the left (first) vertical line of the graticule and the fourth vertical line.

o. Repeat parts c through n of this step until optimum timing and linearity is obtained.

37. Check Normal Sweep Timing Accuracy

a. Change the following control settings:

TRIGGER	Stable positive-slope triggering
×10 HORIZ MAG	Pushed in

TABLE 6-4

Normal Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/ division)	Allowable error for given accuracy
5 μs	5 microsceond	1	0.24 division (within 3%)
10 μs	10 microsecond	1	
20 μs	10 microsecond	2	
50 μs	50 microsecond	1	
.1 ms	0.1 millisecond	1	
.2 ms	0.1 millisecond	2	
.5 ms	0.5 millisecond	1	
1 ms	1 millisecond	1	
2 ms	1 millisecond	2	
5 ms	5 millisecond	1	
10 ms	10 millisecond	1	
20 ms	10 millisecond	2	
50 ms	50 millisecond	1	
.1 s	0.1 second	1	
.2 s	0.1 second	2	
.5 s	0.5 second	1	0.32 division (within 4%)
1 s	1 second	1	

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 6-4, check normal sweep timing within the given tolerances over the middle eight divisions of the display. Set the TRIGGER control as necessary for a stable display in the variable positive-slope area.

38. Check Magnified Sweep Timing Accuracy

a. Change the following control settings:

TRIGGER	Stable positive-slope triggering
×10 HORIZ MAG	Pulled out

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 6-5, check magnified timing within the given tolerances over the middle eight-division portion of the total magnified sweep length. Set the TRIGGER control as necessary for a stable display in the variable positive-slope area.

c. Disconnect all test equipment and remove the calibration shield.

TABLE 6-5

Magnified Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/ division)	Allowable error for given accuracy
5 μs	0.5 microsecond	1	0.4 division (within 5%)
10 μs	1 microsecond	1	
20 μs	1 microsecond	2	0.32 division (within 4%)
50 μs	5 microsecond	1	
.1 ms	10 microsecond	1	
.2 ms	10 microsecond	2	
.5 ms	50 microsecond	1	
1 ms	0.1 millisecond	1	
2 ms	0.1 millisecond	2	
5 ms	0.5 millisecond	1	
10 ms	1 millisecond	1	
20 ms	1 millisecond	2	
50 ms	5 millisecond	1	
.1 s	10 millisecond	1	
.2 s	10 millisecond	2	
.5 s	50 millisecond	1	0.4 division (within 5%)
1 s	0.1 second	1	

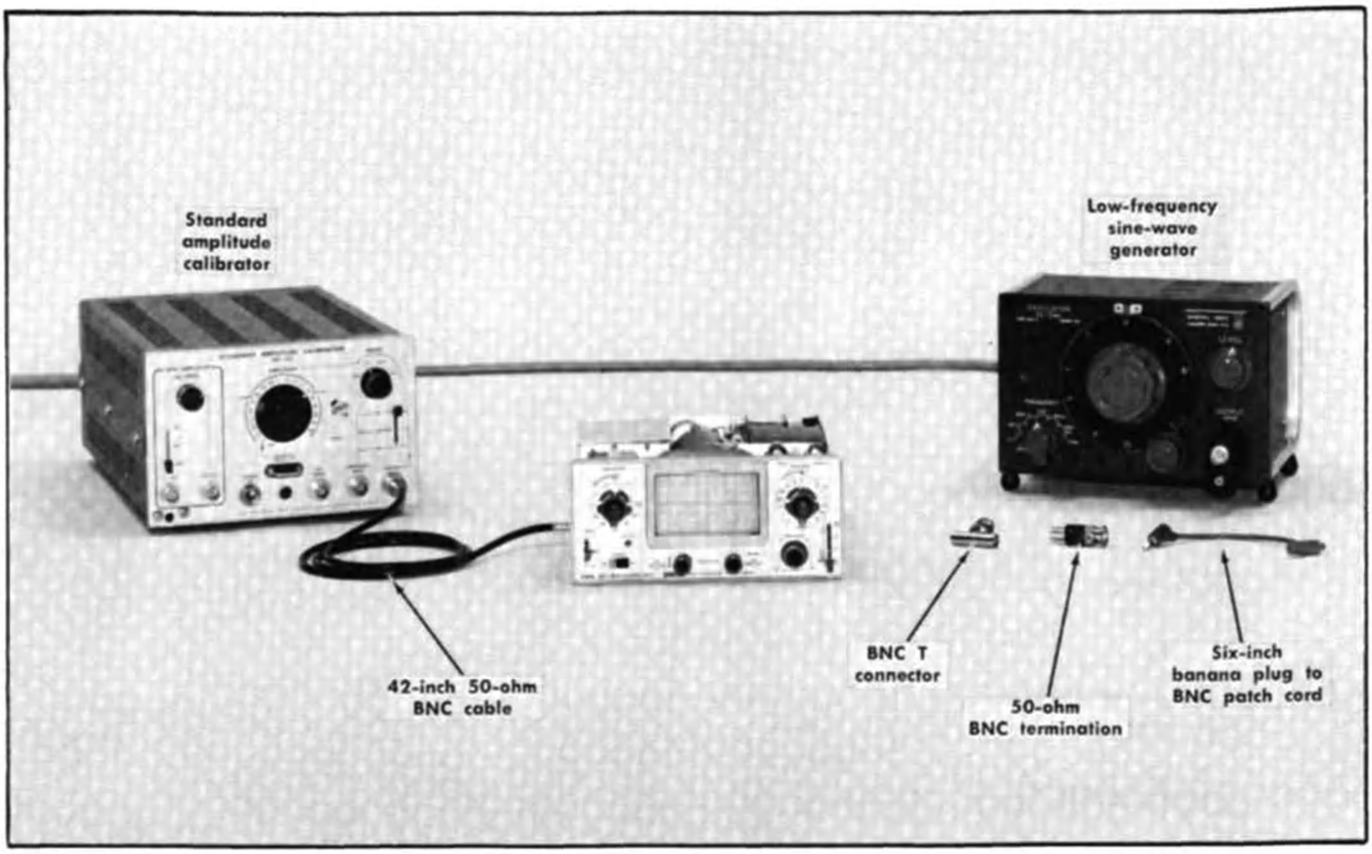


Fig. 6-18. Initial test equipment setup for steps 39 through 45.

Vertical Controls	
VOLTS/DIV	.5
VARIABLE	CAL
INPUT	**GND**
Vertical POSITION	Midrange
×10 VERT GAIN	Pushed in
Triggering Controls	
TRIGGER	**+ AUTO**
Trig/Horiz Coupling	**EXT TRIG OR HORIZ DC**
EXT TRIG OR HORIZ ATTEN (side panel)	**1×**
Horizontal Controls	
TIME/DIV	**EXT HORIZ**
VARIABLE	CAL
Horizontal POSITION	Midrange
×10 HORIZ MAG	Pulled out
CRT Controls	
FOCUS	Adjust for focused display
INTENSITY	Adjust for visible display
Power Controls	
POWER	ON
Power Pack (rear panel)	EXT DC

39. Adjust External Horizontal Variable Balance **0**

a. Test equipment setup is shown in Fig. 6-18.

b. Position the dot to the center of the graticule with the POSITION controls.

c. CHECK—Rotate the EXT HORIZ VAR control (VARIABLE TIME/DIV) throughout its range. Dot should not move horizontally.

d. ADJUST—Ext Horiz Var Bal adjustment, R218 (see Fig. 6-19), for no trace shift as the EXT HORIZ VAR control is rotated. If necessary, use the horizontal POSITION control to keep the dot on the screen during adjustment.

40. Check External Horizontal Deflection Factor

a. Change the following control settings:

EXT HORIZ VAR	CAL (clockwise)
×10 HORIZ MAG	Pushed in

b. Position the dot to the left vertical line of the graticule with the horizontal POSITION control.

c. Connect the standard amplitude calibrator to the EXT TRIG OR HORIZ INPUT connector with the 42-inch BNC cable.

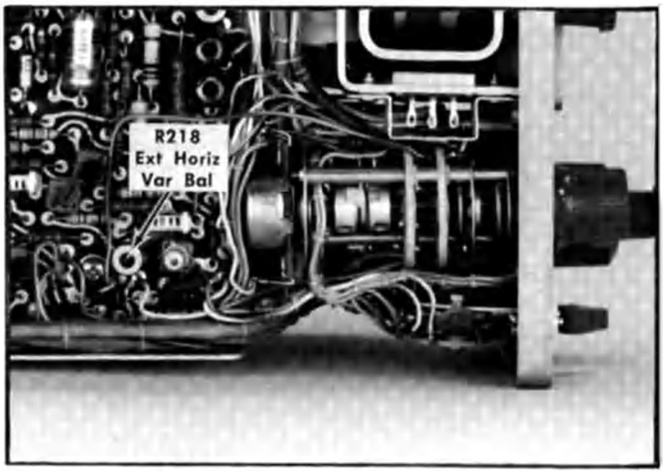


Fig. 6-19. Location of external horizontal variable balance adjustment (Main board).

d. Set the standard amplitude calibrator for a two-volt square-wave output.

e. CHECK—CRT display for horizontal deflection of 6.7 to 10 divisions between dots (200 to 300 millivolts/division).

41. Check External Horizontal Deflection Factor with 10× Attenuation

a. Set the EXT TRIG OR HORIZ ATTEN switch (side panel) to 10×.

b. Set the standard amplitude calibrator for a 20-volt square-wave output.

c. CHECK—CRT display for horizontal deflection of 6.7 to 10 divisions between dots (two to three volts/division).

42. Check External Horizontal Variable Control Range

a. Turn the EXT HORIZ VAR control fully counterclockwise.

b. CHECK—CRT display not more than one-tenth of the deflection measured in previous step (10:1 range or greater).

43. Check External Horizontal Coupling

a. Position the left dot of the display to the center vertical line with the horizontal POSITION control.

b. Set the Trig/Horiz Coupling switch to EXT TRIG AC.

c. CHECK—CRT display for horizontal deflection centered about the center vertical line.

d. Disconnect all test equipment.

44. Check External Horizontal Bandwidth

a. Change the following control settings:

EXT TRIG OR HORIZ ATTEN	1×
EXT HORIZ VAR	CAL (fully clockwise)

b. Connect the low-frequency sine-wave generator to the EXT TRIG OR HORIZ INPUT connector through the 42-inch 50-ohm BNC cable and 50-ohm BNC termination.

c. Set the low-frequency generator for six-division horizontal deflection, centered about the center vertical line, at one kilohertz.

d. Without changing the output amplitude, increase the output frequency of the generator to 10 kilohertz.

e. CHECK—CRT display 4.2 divisions, or greater, horizontal deflection (not more than —3 dB).

f. Disconnect all test equipment.

45. Check External Blanking

a. Change the following control settings:

VOLTS/DIV	2
INPUT	DC
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	5 μs

b. Connect the low-frequency generator to the VERT INPUT connector through the 42-inch BNC cable and the BNC T connector.

c. Set the low-frequency generator for a five-division display (five volt positive peaks) at 100 kilohertz.

d. Connect the output of the BNC T connector to the EXT BLANK jack with the six-inch BNC to banana plug patch cord.

e. CHECK—CRT display for blanking of a portion of each cycle of the waveform (see Fig. 6-20). The INTENSITY control setting may need to be changed to show blanking.

f. Disconnect all test equipment.

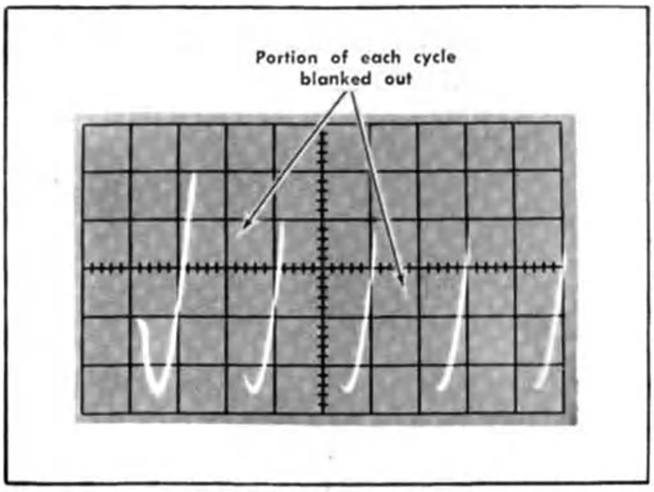


Fig. 6-20. Typical CRT display when checking external blanking.

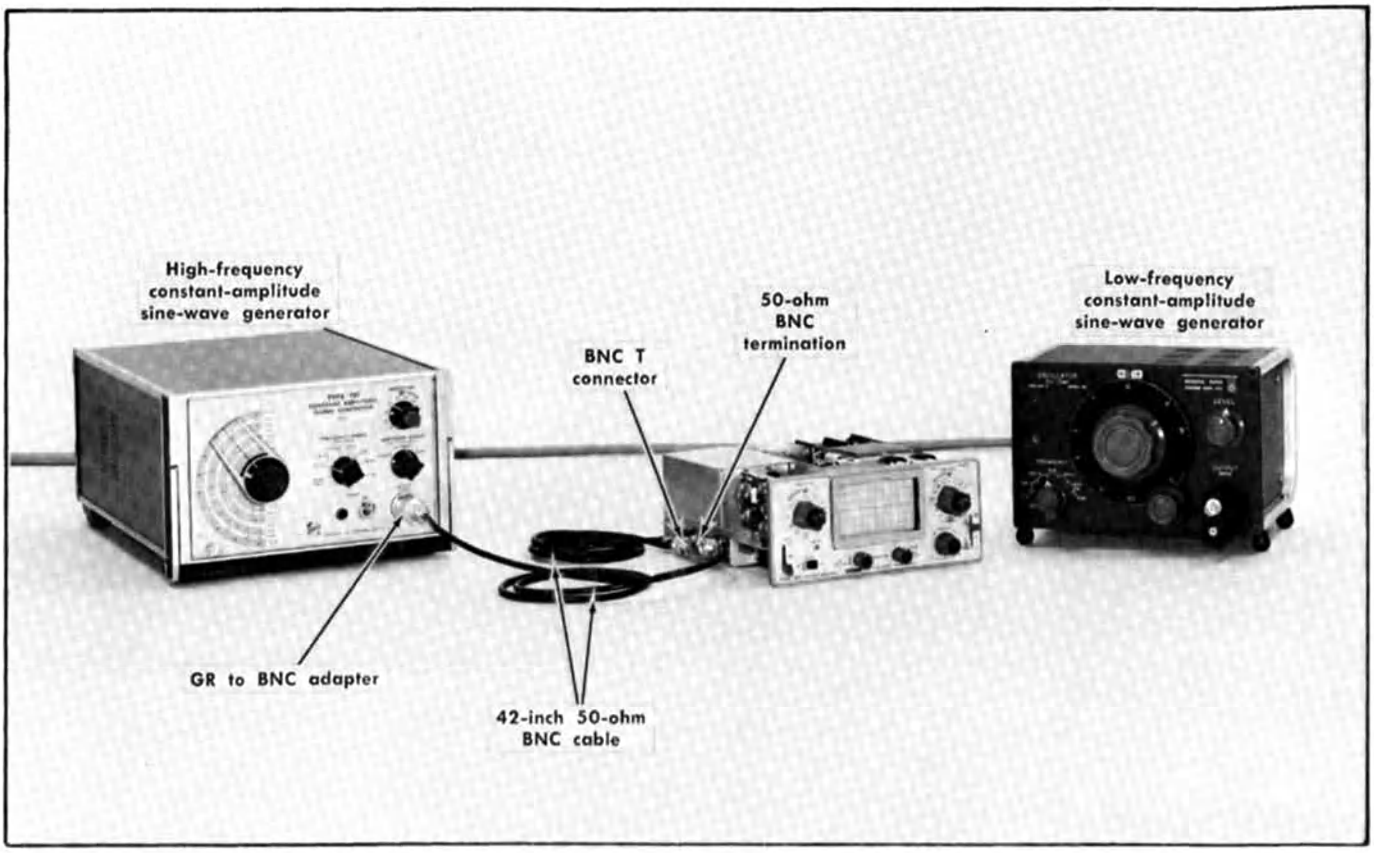


Fig. 6-21. Initial test equipment setup for steps 46 through 54.

Vertical Controls	
VOLTS/DIV	.1
VARIABLE	CAL
INPUT	DC
Vertical POSITION	Midrange
X10 VERT GAIN	Pushed in
Triggering Controls	
TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
EXT TRIG OR HORIZ ATTEN (side panel)	1×
Horizontal Controls	
TIME/DIV	5 μs
VARIABLE	CAL
Horizontal POSITION	Midrange
×10 HORIZ MAG	Pushed in
CRT Controls	
FOCUS	Adjust for focused display
INTENSITY	Adjust for visible display
Power Controls	
POWER	ON
Power Pack (rear panel)	EXT DC

46. Check Internal Triggering Operation

a. Test equipment setup is shown in Fig. 6-21.

b. Connect the high-frequency constant-amplitude sine-wave generator to the VERT INPUT connector through the GR to BNC adapter, 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG OR HORIZ INPUT connector with a 42-inch 50-ohm BNC cable.

c. Set the constant-amplitude generator for a 0.3-division display at 400 kilohertz.

d. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

e. Turn the TRIGGER control clockwise to the variable positive-slope area.

f. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

g. Turn the TRIGGER control clockwise to the variable negative-slope area.

h. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

i. Set the TRIGGER control to — AUTO.

j. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

k. Set the constant-amplitude generator for a 0.75-division display at four megahertz.

l. Pull the ×10 HORIZ MAG switch out.

m. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ. TRIGGER control may be adjusted as necessary to obtain a stable display.

r. Set the TRIGGER control to + AUTO.

s. CHECK—Stable CRT display is presented with the Trig/Horiz Coupling switch set to INT TRIG AC and ACLF REJ.

47. Check External Triggering Operation

a. Change the following control settings:

Trig/Horiz Coupling	EXT TRIG OR HORIZ AC
×10 HORIZ MAG	Pushed in

b. Set the constant-amplitude generator for a 0.75-division display (75 millivolts) at 400 kilohertz.

c. CHECK—Stable CRT display is presented.

d. Turn the TRIGGER control clockwise to the variable positive-slope area.

e. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

f. Turn the TRIGGER control clockwise to the variable negative-slope area.

g. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

h. Set the TRIGGER control to — AUTO.

i. CHECK—Stable CRT display is presented.

j. Set the constant-amplitude generator for a 1.9-division display (190 millivolts) at 400 kilohertz.

k. Without changing the output amplitude, set the generator to four megahertz.

l. Pull the ×10 HORIZ MAG switch out.

m. CHECK—Stable CRT display is presented.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

r. Set the TRIGGER control to + AUTO.

s. CHECK—Stable CRT display is presented.

t. Disconnect the high-frequency generator.

48. Check Low-Frequency Triggering Operation

a. Connect the low-frequency constant-amplitude sine-wave generator to the VERT INPUT connector through the 42-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the EXT TRIG OR HORIZ INPUT connector with a 42-inch 50-ohm BNC cable.

b. Change the following control settings:

TIME/DIV	10 ms
×10 HORIZ MAG	Pushed in

c. Set the low-frequency generator for a 0.75-division display (75 millivolts) at 30 hertz.

d. CHECK—Stable CRT display is presented.

e. Turn the TRIGGER control clockwise to the variable positive-slope area.

f. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ AC and DC. TRIGGER control may be adjusted as necessary to obtain a stable display.

g. Turn the TRIGGER control clockwise to the variable negative-slope area.

h. CHECK—Stable CRT display can be obtained with the Trig/Horiz Coupling switch set to EXT TRIG OR HORIZ, AC and DC. TRIGGER Control may be adjusted as necessary to obtain a stable display.

i. Set the TRIGGER control to — AUTO.

j. CHECK—Stable CRT display is presented.

k. Set the Trig/Horiz Coupling switch to INT TRIG AC.

l. Set the low-frequency generator for a 0.3-division display at 30 hertz.

m. CHECK—Stable CRT display is presented.

n. Turn the TRIGGER control counterclockwise to the variable negative-slope area.

o. CHECK—Stable CRT display can be obtained with the TRIGGER control.

p. Turn the TRIGGER control counterclockwise to the variable positive-slope area.

q. CHECK—Stable CRT display can be obtained with the TRIGGER control.

r. Set the TRIGGER control to + AUTO.

s. CHECK—Stable CRT display is presented.

49. Check Low-Frequency Reject Operation

a. Change the following control settings:

Trig/Horiz Coupling	INT TRIG ACLF REJ
TIME/DIV	.1 ms

b. Set the low-frequency generator for a 0.3-division display at 30 kilohertz.

c. CHECK—Stable CRT display can be obtained with the TRIGGER control set to + and — AUTO and in the variable positive- and negative-slope areas (adjust as necessary).

d. Without changing the output amplitude, set the low-frequency generator to 30 hertz.

e. Set the TIME/DIV switch to 10 ms.

f. CHECK—Stable CRT display cannot be obtained at any setting of the TRIGGER control.

50. Check Trigger Slope Operation

a. Change the following control settings:

TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	.5 ms

b. Set the low-frequency generator for a four-division display at one kilohertz.

c. CHECK—CRT display starts on the positive slope of the waveform (see Fig. 6-22A).

d. Turn the TRIGGER control clockwise until a stable display is obtained in the positive-slope area.

e. CHECK—CRT display starts on the positive slope of the waveform.

f. Turn the TRIGGER control clockwise until a stable display is obtained in the negative-slope area.

g. CHECK—CRT display starts on the negative slope of the waveform (see Fig. 6-22B).

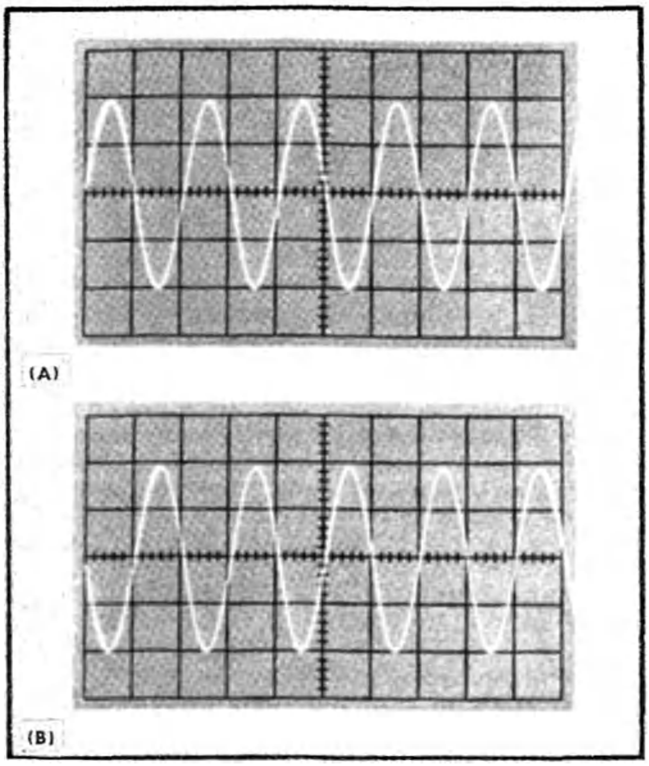


Fig. 6-22. (A) Typical CRT display when checking positive-slope triggering, (B) typical CRT display when checking negative-slope triggering.

h. Set the TRIGGER control to — AUTO.

i. CHECK—CRT display starts on the negative slope of the waveform.

51. Check TRIGGER Control Range

a. Remove the 50-ohm BNC termination and reconnect the low-frequency sine-wave generator to the BNC T connector through the 42-inch BNC cable.

b. Change the following control settings:

VOLTS/DIV	.5
TRIGGER	+ AUTO
Trig/Horiz Coupling	EXT TRIG AC

c. Set the low-frequency generator for a 3.2-division display (1.6 volts peak to peak) at one kilohertz.

d. CHECK—Rotate the TRIGGER control throughout the positive-slope area and check that the display can be triggered (stable display) at any point along the positive slope of the waveform (indicates TRIGGER control range of at least + and — 0.8 volts). Display is not triggered at either extreme of the positive-slope area except in + AUTO detent.

e. CHECK—Rotate the TRIGGER control throughout the negative-slope area and check that the display can be triggered at any point along the negative slope of the waveform. Display is not triggered at either extreme of the negative-slope area except in — AUTO detent.

f. Change the following control settings:

VOLTS/DIV	5
TRIGGER	+ AUTO
EXT TRIG OR HORIZ ATTEN	10×

g. Set the low-frequency generator for a 3.2-division display (16 volts peak to peak) at one kilohertz.

h. CHECK—Rotate the TRIGGER control throughout the positive-slope area and check that the display can be triggered at any point along the positive slope of the waveform. Display is not triggered at either extreme of the positive-slope area except in + AUTO detent.

i. CHECK—Rotate the TRIGGER control throughout the negative-slope area and check that the display can be triggered at any point along the negative slope of the waveform. Display is not triggered at either extreme of the negative-slope area except in — AUTO detent.

j. Disconnect all test equipment.

52. Check Calibrator Risetime

a. Change the following control settings:

VOLTS/DIV	5 DIV CAL
INPUT	GND
TRIGGER	— AUTO
Trig/Horiz Coupling	INT TRIG AC
TIME/DIV	.1 ms
×10 HORIZ MAG	Pulled out

b. Position the rising portion of the waveform onto the viewing area with the horizontal POSITION control and center the display with the vertical POSITION control.

c. CHECK—CRT display for 0.2 division or less horizontal distance between the 10% and 90% points on the leading edge of the calibrator waveform (two microseconds or less risetime).

53. Check Calibrator Repetition Rate

a. Change the following control settings:

TRIGGER	+ AUTO
TIME/DIV	.2 ms
×10 HORIZ MAG	Pushed in

b. Position the start of the trace to the left (first) vertical line of the graticule.

c. CHECK—CRT display for duration of one cycle between 5 and 10 divisions (repetition rate 750 hertz, ±250 hertz).

54. Check Calibrator Duty Cycle

a. Set the TIME/DIV switch to .1 ms.

b. Set the VARIABLE TIME/DIV control for one complete cycle in 10 divisions.

c. CHECK—CRT display for length of positive segment of the square wave between four and six divisions (duty cycle 40% to 60%).

d. Return the VARIABLE TIME/DIV control to CAL.

NOTE

Accuracy of the Calibrator output voltage was set in step 4 of this procedure.

This completes the calibration procedure for the Type 323. Disconnect all test equipment and replace the cabinet. If the instrument has been completely checked and calibrated to the tolerances given in this procedure, it will meet the electrical characteristics listed in the Performance Requirement column of the Type 323 Specification section of this manual.

PARTS LIST ABBREVIATIONS

BHB	binding head brass
BHS	binding head steel
cap.	capacitor
cer	ceramic
comp	composition
conn	connector
CRT	cathode-ray tube
csk	countersunk
DE	double end
dia	diameter
div	division
elect.	electrolytic
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ext	external
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
h	height or high
hex.	hexagonal
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
ID	inside diameter
incd	incandescent
int	internal
lg	length or long
met.	metal
mtg hdw	mounting hardware
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
PHB	pan head brass
PHS	pan head steel
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
RHB	round head brass
RHS	round head steel
SE	single end
SN or S/N	serial number
SW	switch
TC	temperature compensated
THB	truss head brass
thk	thick
THS	truss head steel
tub.	tubular
var	variable
w	wide or width
WW	wire-wound

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

SPECIAL NOTES AND SYMBOLS

×000	Part first added at this serial number
00×	Part removed after this serial number
*000-0000-00	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components.
Use 000-0000-00	Part number indicated is direct replacement.
◐	Screwdriver adjustment.
▭	Control, adjustment or connector.

SECTION 7
ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Bulbs			
B509	150-0084-00			Neon GE 2AA			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C1	283-0059-00			1 μF	Cer	25 V	+80%—20%
C2	283-0059-00			1 μF	Cer	25 V	+80%—20%
C3	290-0183-01			1 μF	Elect.	35 V	10%
C5	283-0023-00			0.1 μF	Cer	10 V	
C6	290-0183-01			1 μF	Elect.	35 V	10%
C19	283-0003-01			0.01 μF	Cer	150 V	
C20	*285-0610-00			0.1 μF	MT	600 V	10%
C23A	281-0093-01			5.5-18 pF, Var	Cer		
C23B	281-0091-01			2-8 pF, Var	Cer		
C23C	281-0600-00			35 pF	Cer		10%
C24A	281-0093-01			5.5-18 pF, Var	Cer		
C24B	281-0091-01			2-8 pF, Var	Cer		
C24C	283-0597-01			470 pF	Mica	300 V	10%
C25A	281-0093-01			5.5-18 pF, Var	Cer		
C25B	281-0091-01			2-8 pF, Var	Cer		
C25C	283-0617-00	300000	300305	4700 pF	Mica	300 V	10%
C25C	283-0617-01	300306		4700 pF	Mica	300 V	10%
C28A	281-0091-01			2-8 pF, Var	Cer		
C28B	281-0093-01			5.5-18 pF, Var	Cer		
C28C	281-0592-00			4.7 pF	Cer	500 V	±0.5 pF
C29A	281-0093-01			5.5-18 pF, Var	Cer		
C29B	281-0091-01			2-8 pF, Var	Cer		
C31	283-0068-00			0.01 μF	Cer	500 V	
C33	290-0183-01			1 μF	Elect.	35 V	10%
C50	281-0627-00			1 pF	Cer	600 V	
C56	283-0003-01			0.01 μF	Cer	150 V	
C58	281-0627-00			1 pF	Cer	600 V	
C68	281-0603-00			39 pF	Cer	500 V	5%
C88	281-0504-00			10 pF	(nominal value) Selected		
C102	281-0622-00			47 pF	Cer	500 V	1%
C107	281-0622-00			47 pF	Cer	500 V	1%
C115	283-0003-01			0.01 μF	Cer	150 V	
C133	283-0003-01			0.01 μF	Cer	150 V	
C143	283-0119-00			2200 pF	Cer	200 V	5%
C153	283-0003-01			0.01 μF	Cer	150 V	
C155	283-0032-01			470 pF	Cer	500 V	5%
C158	283-0032-01			470 pF	Cer	500 V	5%

Capacitors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C160	281-0064-00			0.25-1.5 pF, Var	Tub.		
C162	283-0083-01			0.0047 μF	Cer	500 V	5%
C167	281-0524-00			150 pF	Cer	500 V	
C169	283-0003-01			0.01 μF	Cer	150 V	
C170	281-0064-00			0.25-1.5 pF, Var	Tub.		
C172	283-0083-01			0.0047 μF	Cer	500 V	5%
C177	281-0524-00			150 pF	Cer	500 V	
C191	290-0271-00			9 μF	Elect.	125 V	+20%—15%
C201	281-0064-00			0.25-1.5 pF, Var	Tub.		
C206	281-0060-01			2-8 pF, Var	Cer		
C208	283-0602-00			53 pF	Mica	300 V	5%
C209	283-0068-00			0.01 μF	Cer	500 V	
C212	283-0104-01			2000 pF	Cer	500 V	5%
C221	290-0136-01			2.2 μF	Elect.	20 V	
C223	283-0119-00			2200 pF	Cer	200 V	5%
C241	283-0003-01			0.01 μF	Cer	150 V	
C250	290-0183-01			1 μF	Elect.	35 V	10%
C252	281-0578-00	300000	300294	18 pF	Cer	500 V	5%
C252	281-0523-00	300295		100 pF	Cer	350 V	
C256	281-0578-00			18 pF	Cer	500 V	5%
C270A	290-0134-01			22 μF	Elect.	15 V	
C270B	290-0136-01			2.2 μF	Elect.	20 V	
C270C	290-0264-01			0.22 μF	Elect.	35 V	10%
C290	290-0183-01			1 μF	Elect.	35 V	10%
C293	290-0183-01			1 μF	Elect.	35 V	10%
C301	281-0504-00	300000	300030	10 pF	Cer	500 V	10%
C301	281-0578-00	300031		18 pF	Cer	500 V	5%
C310	290-0183-01			1 μF	Elect.	35 V	10%
C313	283-0003-01			0.01 μF	Cer	150 V	
C316	281-0550-00			120 pF	Cer	500 V	10%
C321	290-0183-01			1 μF	Elect.	35 V	10%
C330A				1 μF			
C330B	*295-0110-00			0.01 μF	(Matched Assy)		
C330C				0.001 μF			
C340A	290-0183-01			1 μF	Elect.	35 V	10%
C340B	283-0003-01			0.01 μF	Cer	500 V	10%
C342	283-0000-01			0.001 μF	Cer	500 V	
C353	281-0550-00			120 pF	Cer	500 V	10%
C359	290-0183-01			1 μF	Elect.	35 V	10%
C361	283-0003-01			0.01 μF	Cer	150 V	
C362	283-0119-00			2200 pF	Cer	200 V	5%
C364	283-0103-00			180 pF	Cer	500 V	5%
C369	283-0003-01			0.01 μF	Cer	150 V	
C432	281-0064-00			0.25-1.5 pF, Var	Tub.		
C433	281-0544-00			5.6 pF	Cer	500 V	10%
C446	281-0091-01			2-8 pF, Var	Cer		

Capacitors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
C454	281-0091-01			2-8 pF, Var	Cer		
C457	281-0627-00			1 pF	Cer	600 V	
C491	290-0134-01			22 μF	Elect.	15 V	
C493	290-0183-01			1 μF	Elect.	35 V	10%
C507	290-0164-00			1 μF	Elect.	150 V	
C512	290-0183-01			1 μF	Elect.	35 V	10%
C526	283-0059-00			1 μF	Cer	25 V	+80%—20%
C529	290-0248-02			150 μF	Elect.	15 V	
C531	283-0003-01			0.01 μF	Cer	150 V	
C533	283-0008-00			0.1 μF	Cer	500 V	
C540	283-0092-00			0.03 μF	Cer	200 V	+80%—20%
C541	283-0092-00			0.03 μF	Cer	200 V	+80%—20%
C543	290-0305-00			3 μF	Elect.	150 V	
C545	290-0134-01	300000	301900	22 μF	Elect.	15 V	
C545	290-0134-02	301901		22 μF	Elect.	15 V	
C550	290-0114-01	300000	301900	47 μF	Elect.	6 V	
C550	290-0114-02	301901		47 μF	Elect.	6 V	10%
C554	283-0003-01			0.01 μF	Cer	150 V	
C559	290-0134-01			22 μF	Elect.	15 V	
C560	290-0114-01	300000	301900	47 μF	Elect.	6 V	
C560	290-0114-02	301901		47 μF	Elect.	6 V	10%
C563	283-0003-01			0.01 μF	Cer	150 V	
C564	283-0003-01			0.01 μF	Cer	150 V	
C569	290-0134-01			22 μF	Elect.	15 V	
C572	290-0167-01			10 μF	Elect.	15 V	
C573	283-0013-00			0.01 μF	Cer	1000 V	
C574	283-0013-00			0.01 μF	Cer	1000 V	
C575A-G	283-0151-00			Capacitor Assy (7 section)			
C576A-G	283-0151-00			Capacitor Assy (7 section)			
C577	283-0013-00			0.01 μF	Cer	1000 V	
C578	283-0013-00			0.01 μF	Cer	1000 V	
C579	283-0105-00			0.01 μF	Cer	2000 V	+80%—20%
C589	283-0003-01	300000	300225	0.01 μF	Cer	150 V	
C589	283-0068-00	300226		0.01 μF	Cer	500 V	

Semiconductor Device, Diodes

D11	*152-0185-00	Silicon	Replaceable by 1N4152
D12	*152-0185-00	Silicon	Replaceable by 1N4152
D13	*152-0185-00	Silicon	Replaceable by 1N4152
D30	152-0246-00	Silicon	Low leakage 250 mW 40 V
D31	152-0246-00	Silicon	Low leakage 250 mW 40 V
D32	152-0246-00	Silicon	Low leakage 250 mW 40 V
D33	152-0246-00	Silicon	Low leakage 250 mW 40 V
D54	*152-0185-00	Silicon	Replaceable by 1N4152
D81	*152-0185-00	Silicon	Replaceable by 1N4152
D82	*152-0185-00	Silicon	Replaceable by 1N4152

Semiconductor Device, Diodes *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc		Description
D83	*152-0185-00			Silicon	Replaceable by 1N4152
D84	*152-0185-00			Silicon	Replaceable by 1N4152
D85	*152-0185-00			Silicon	Replaceable by 1N4152
D86	152-0071-00			Germanium	ED 2007
D87	152-0071-00			Germanium	ED 2007
D88	152-0071-00			Germanium	ED 2007
D89	152-0071-00			Germanium	ED 2007
D169	*152-0185-00			Silicon	Replaceable by 1N4152
D213	152-0246-00			Silicon	Low leakage 250 mW 40 V
D214	152-0246-00			Silicon	Low leakage 250 mW 40 V
D301	*152-0185-00			Silicon	Replaceable by 1N4152
D303	152-0330-00			Tunnel	Ip = 2.2 mA Cv = 10 pF
D305	*152-0185-00			Silicon	Replaceable by 1N4152
D309	152-0246-00			Silicon	Low leakage 250 mW 40 V
D342	*152-0185-00			Silicon	Replaceable by 1N4152
D343	*152-0185-00			Silicon	Replaceable by 1N4152
D350	*152-0185-00			Silicon	Replaceable by 1N4152
D351	*152-0185-00			Silicon	Replaceable by 1N4152
D353	*152-0185-00			Silicon	Replaceable by 1N4152
D416	*152-0185-00			Silicon	Replaceable by 1N4152
D442	152-0127-00			Zener	1N755A 400 mW 7.5 V 5%
D452	*152-0185-00			Silicon	Replaceable by 1N4152
D501	*152-0107-00			Silicon	Replaceable by 1N647
D516	*152-0185-00			Silicon	Replaceable by 1N4152
D521	*152-0185-00			Silicon	Replaceable by 1N4152
D523	*152-0185-00			Silicon	Replaceable by 1N4152
D525	*152-0061-00			Silicon	Tek Spec
D528	*152-0061-00			Silicon	Tek Spec
D531	*152-0061-00			Silicon	Tek Spec
D533	*152-0061-00			Silicon	Tek Spec
D540	*152-0061-00			Silicon	Tek Spec
D543	*152-0061-00			Silicon	Tek Spec
D545	152-0333-00			Silicon	High Speed and Conductance
D547	152-0359-00			Zener	500 mW 9 V 5% 0.01%/°C TC
D549	152-0333-00			Silicon	High Speed and Conductance
D550	152-0333-00			Silicon	High Speed and Conductance
D554	*152-0185-00			Silicon	Replaceable by 1N4152
D560	152-0333-00			Silicon	High Speed and Conductance
D561	152-0333-00			Silicon	High Speed and Conductance
D565	*152-0185-00			Silicon	Replaceable by 1N4152
D570	152-0333-00			Silicon	High Speed and Conductance
D575A-N (13)	152-0331-00			Silicon	800 V 25 mA 1.0 μs Reverse Recovery Time
D593	152-0281-00			Zener	1N969B 400 mW 22 V 5%

Fuses

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
F501	159-0064-00			1 A	Fast-Blo

Connectors

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
J15	136-0140-00			Socket, Banana Jack Assy
J20	131-0274-00			BNC
J205	131-0106-00			1 Contact, Female
J350	136-0140-00			Socket, Banana Jack Assy

Inductors

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
L46	*108-0489-00			1.2 μH
L501	*108-0464-00			125 μH
L559	*108-0463-00			35 μH
L569	*108-0463-00			35 μH
L590	276-0525-00			Core, Ferrite
L592	*108-0465-00			Trace Rotator

Transistors

Ckt. No.	Tektronix Part No.	Eff	Disc	Description	
Q1	151-0190-00			Silicon	2N3904
Q9	151-0190-00			Silicon	2N3904
Q33A,B	151-1010-00			Silicon	Dual FET
Q41A,B	151-0232-00			Silicon	Dual
Q50	151-0221-00			Silicon	2N4258
Q53	151-0190-00			Silicon	2N3904
Q55	151-0190-00			Silicon	2N3904
Q58	151-0221-00			Silicon	2N4258
Q61	151-0190-00			Silicon	2N3904
Q71	151-0190-00			Silicon	2N3904
Q91	151-0221-00			Silicon	2N4258
Q99	151-0221-00			Silicon	2N4258
Q103	151-0190-00			Silicon	2N3904
Q109	151-0190-00			Silicon	2N3904
Q111	151-0190-00			Silicon	2N3904
Q117	151-0190-00			Silicon	2N3904
Q121	151-0190-00			Silicon	2N3904
Q127	151-0190-00			Silicon	2N3904
Q133	151-0234-00			Silicon	2SC805
Q137	151-0234-00			Silicon	2SC805
Q141	151-0190-00			Silicon	2N3904
Q151	151-0190-00			Silicon	2N3904
Q153	151-0190-00			Silicon	2N3904
Q160	*151-0228-00			Silicon	Tek Spec
Q163	151-0234-00			Silicon	2SC805

Transistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
Q170	*151-0228-00			Silicon	Tek Spec
Q173	151-0234-00			Silicon	2SC805
Q215	151-1018-00			Silicon	FET
Q231	*151-0192-00			Silicon	Replaceable by MP5 6521
Q239	*151-0192-00			Silicon	Replaceable by MP5 6521
Q253	*151-0192-00			Silicon	Replaceable by MPS 6521
Q263	*151-0192-00			Silicon	Replaceable by MPS 6521
Q305	151-0190-00			Silicon	2N3904
Q311	151-1018-00			Silicon	FET
Q317	151-0190-00			Silicon	2N3904
Q326	151-0220-00			Silicon	2N4122
Q343	151-0190-00			Silicon	2N3904
Q356	151-0220-00			Silicon	2N4122
Q363	151-0234-00			Silicon	2SC805
Q370	*151-0228-00			Silicon	Tek Spec
Q373	151-0234-00			Silicon	2SC805
Q415	*151-0192-00			Silicon	Replaceable by MPS 6521
Q420	151-0220-00			Silicon	2N4122
Q427	151-0233-00			Silicon	2SC805 High Voltage Selector
Q440	*151-0228-00			Silicon	Tek Spec
Q450	*151-0228-00			Silicon	Tek Spec
Q459	151-0233-00			Silicon	2SC805 High Voltage Selector
Q505	151-0179-00			Silicon	2N3877A
Q515	151-0190-00			Silicon	2N3904
Q518	*151-0219-00			Silicon	Replaceable by 2N4250
Q525	151-0231-00			Silicon	2SC756-4
Q529	151-0231-00			Silicon	2SC756-4
Q555	151-0190-00			Silicon	2N3904
Q557	151-0190-00			Silicon	2N3904
Q558	151-0164-00			Silicon	2N3702
Q562	151-0220-00			Silicon	2N4122
Q567	151-0190-00			Silicon	2N3904
Q569	151-0207-00			Silicon	2N3415

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

R1	315-0100-01	10 Ω	¼ W		5%
R2	315-0100-01	10 Ω	¼ W		5%
R3	315-0102-01	1 kΩ	¼ W		5%
R4	315-0752-01	7.5 kΩ	¼ W		5%
R6	315-0331-01	330 Ω	¼ W		5%
R8	315-0103-02	10 kΩ	¼ W		5%
R9	315-0822-01	8.2 kΩ	¼ W		5%
R12	321-0316-30	19.1 kΩ	⅛ W	Prec	1%
R13	321-0318-30	20 kΩ	⅛ W	Prec	1%
R15	321-0336-30	30.9 kΩ	⅛ W	Prec	1%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R17	321-0753-31			9 kΩ	1/8 W	Prec	1/2%
R18	321-0754-31			900 Ω	1/8 W	Prec	1/2%
R19	321-0636-00			100 Ω	1/8 W	Prec	1/2%
R21	315-0104-02			100 kΩ	1/4 W		5%
R23B	322-0621-31			900 kΩ	1/4 W	Prec	1/2%
R23C	321-1389-31			111 kΩ	1/8 W	Prec	1/2%
R24B	322-0624-01			990 kΩ	1/4 W	Prec	1/2%
R24C	321-1289-31			10.1 kΩ	1/8 W	Prec	1/2%
R25B	322-0629-01			999 kΩ	1/4 W	Prec	1/2%
R25C	321-0193-31			1 kΩ	1/8 W	Prec	1/2%
R27	315-0471-02			470 Ω	1/4 W		5%
R28B	322-0610-31			500 kΩ	1/4 W	Prec	1/2%
R28C	322-0481-01			1 MΩ	1/4 W	Prec	1/2%
R29B	322-0620-31			800 kΩ	1/4 W	Prec	1/2%
R29C	321-0733-01	300000	300894	250 kΩ	1/8 W	Prec	1/2%
R29C	321-0618-01	300895		250 kΩ	1/8 W	Prec	1/2%
R30	322-0481-00			1 MΩ	1/4 W	Prec	1%
R31	321-0385-30			100 kΩ	1/8 W	Prec	1%
R33	315-0201-01			200 Ω	1/4 W		5%
R34	321-0068-30			49.9 Ω	1/8 W	Prec	1%
R36	321-0249-30			3.83 kΩ	1/8 W	Prec	1%
R38	321-0249-30			3.83 kΩ	1/8 W	Prec	1%
R39	311-0622-00			100 Ω, Var			
R40	311-0634-00			500 Ω, Var			
R42	321-0223-30			2.05 kΩ	1/8 W	Prec	1%
R44	321-0210-30			1.5 kΩ	1/8 W	Prec	1%
R46	311-0643-00			50 Ω, Var			
R47	321-0111-30			140 Ω	1/8 W	Prec	1%
R49	321-0223-30			2.05 kΩ	1/8 W	Prec	1%
R51	321-0285-30			9.09 kΩ	1/8 W	Prec	1%
R52	321-0208-30			1.43 kΩ	1/8 W	Prec	1%
R54	315-0432-01			4.3 kΩ	1/4 W		5%
R55	321-0229-30			2.37 kΩ	1/8 W	Prec	1%
R56	321-0286-30			9.31 kΩ	1/8 W	Prec	1%
R59	321-0285-30			9.09 kΩ	1/8 W	Prec	1%
R61	315-0512-01			5.1 kΩ	1/4 W		5%
R62	321-0251-30			4.02 kΩ	1/8 W	Prec	1%
R63	321-0193-30			1 kΩ	1/8 W	Prec	1%
R65	321-0235-30			2.74 kΩ	1/8 W	Prec	1%
R66	311-0605-00			200 Ω, Var			
R68	321-0152-30	300000	300305	374 Ω	1/8 W	Prec	1%
R68	321-0808-00	300306	300765	300 Ω	1/8 w	Prec.	1%
R68	321-0824-30	300766		330 Ω	1/8 W	Prec	1%
R69	311-0605-00			200 Ω, Var			
R71	315-0512-01			5.1 kΩ	1/4 W		5%
R72	321-0251-30			4.02 kΩ	1/8 W	Prec	1%
R73	321-0193-30			1 kΩ	1/8 W	Prec	1%
R75	321-0235-30			2.74 kΩ	1/8 W	Prec	1%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R76	311-0692-00			3 kΩ, Var			
R80	321-0251-30			4.02 kΩ	1/8 W	Prec	1%
R81	315-0243-01			24 kΩ	1/4 W		5%
R82	311-0689-00			2 X 10 kΩ, Var			
R83	315-0243-01			24 kΩ	1/4 W		5%
R84	321-0251-30			4.02 kΩ	1/8 W	Prec	1%
R85	315-0123-01			12 kΩ	1/4 W		5%
R87	321-0313-30			17.8 kΩ	1/8 W	Prec	1%
R89	321-0313-30			17.8 kΩ	1/8 W	Prec	1%
R90	315-0243-01			24 kΩ	1/4 W		5%
R91	311-0607-00			10 kΩ, Var			
R93	311-0607-00			10 kΩ, Var			
R94	315-0243-01			24 kΩ	1/4 W		5%
R95	321-0255-30			4.42 kΩ	1/8 W	Prec	1%
R96	315-0392-01			3.9 kΩ	1/4 W		5%
R98	315-0392-01			3.9 kΩ	1/4 W		5%
R99	321-0255-30			4.42 kΩ	1/8 W	Prec	1%
R101	321-0264-30			5.49 kΩ	1/8 W	Prec	1%
R104	321-0242-30			3.24 kΩ	1/8 W	Prec	1%
R106	321-0242-30			3.24 kΩ	1/8 W	Prec	1%
R108	321-0264-30			5.49 kΩ	1/8 W	Prec	1%
R111	321-0251-30			4.02 kΩ	1/8 W	Prec	1%
R113	315-0101-01			100 Ω	1/4 W		5%
R114	321-0201-30			1.21 kΩ	1/8 W	Prec	1%
R115	321-0284-30			8.87 kΩ	1/8 W	Prec	1%
R118	321-0251-30			4.02 kΩ	1/8 W	Prec	1%
R120	315-0101-01			100 Ω	1/4 W		5%
R123	321-0213-30			1.62 kΩ	1/8 W	Prec	1%
R125	321-0213-30			1.62 kΩ	1/8 W	Prec	1%
R128	315-0101-01			100 Ω	1/4 W		5%
R131	321-0289-30			10 kΩ	1/8 W	Prec	1%
R133	321-0270-30			6.34 kΩ	1/8 W	Prec	1%
R134	321-0318-30			20 kΩ	1/8 W	Prec	1%
R135	321-0239-30			3.01 kΩ	1/8 W	Prec	1%
R137	321-0239-30			3.01 kΩ	1/8 W	Prec	1%
R139	321-0289-30			10 kΩ	1/8 W	Prec	1%
R143	321-0281-30			8.25 kΩ	1/8 W	Prec	1%
R153	315-0102-01			1 kΩ	1/4 W		5%
R160	321-0452-00			499 kΩ	1/8 W	Prec	1%
R161	315-0510-01			51 Ω	1/4 W		5%
R162	315-0620-01			62 Ω	1/4 W		5%
R163	315-0202-01			2 kΩ	1/4 W		5%
R164	321-0114-30			150 Ω	1/8 W	Prec	1%
R166	315-0203-01			20 kΩ	1/4 W		5%
R169	315-0333-01			33 kΩ	1/4 W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R170	321-0452-00			499 kΩ	⅛ W	Prec	1%
R171	315-0510-01			51 Ω	¼ W		5%
R172	315-0620-01			62 Ω	¼ W		5%
R173	315-0202-01			2 kΩ	¼ W		5%
R174	321-0114-30			150 Ω	⅛ W	Prec	1%
R176	315-0203-01			20 kΩ	¼ W		5%
R191	315-0471-02			470 Ω	¼ W		5%
R201	316-0336-01			33 MΩ	¼ W		
R205	315-0471-02			470 Ω	¼ W		5%
R206	322-0621-30			900 kΩ	¼ W	Prec	1%
R208	321-0617-30			111 kΩ	⅛ W	Prec	1%
R210	322-0481-00			1 MΩ	¼ W	Prec	1%
R212	315-0104-02			100 kΩ	¼ W		5%
R217	315-0512-01			5.1 kΩ	¼ W		5%
R218	311-0607-00			10 kΩ, Var			
R230	315-0472-01			4.7 kΩ	¼ W		5%
R232	321-0240-30			3.09 kΩ	⅛ W	Prec	1%
R234	315-0101-01			100 Ω	¼ W		5%
R236	321-0246-30			3.57 kΩ	⅛ W	Prec	1%
R238	321-0240-30			3.09 kΩ	⅛ W	Prec	1%
R239	315-0101-01			100 Ω	¼ W		5%
R242	315-0472-01			4.7 kΩ	¼ W		5%
R244	315-0203-01	300000	300915	20 kΩ	¼ W		5%
R244	315-0183-02	300916		18 kΩ	¼ W		5%
R246	311-0687-00			50 kΩ, Var			
R251	321-0289-30			10 kΩ	⅛ W	Prec	1%
R252	321-0297-30			12.1 kΩ	⅛ W	Prec	1%
R253	321-0339-30			33.2 kΩ	⅛ W	Prec	1%
R254	321-0176-30			665 Ω	⅛ W	Prec	1%
R256	321-0289-30			10 kΩ	⅛ W	Prec	1%
R257	321-0245-30			3.48 kΩ	⅛ W	Prec	1%
R258	321-0268-30			6.04 kΩ	⅛ W	Prec	1%
R260	321-0217-30			1.78 kΩ	⅛ W	Prec	1%
R262	321-0195-30			1.05 kΩ	⅛ W	Prec	1%
R264	321-0260-30			4.99 kΩ	⅛ W	Prec	1%
R290	315-0100-01			10 Ω	¼ W		5%
R293	315-0100-01			10 Ω	¼ W		5%
R301	315-0102-01			1 kΩ	¼ W		5%
R303	321-0252-30			4.12 kΩ	⅛ W	Prec	1%
R304	315-0153-02			15 kΩ	¼ W		5%
R305	321-0281-30			8.25 kΩ	⅛ W	Prec	1%
R307	315-0101-01			100 Ω	¼ W		5%
R308	315-0822-01			8.2 kΩ	¼ W		5%
R310	315-0201-01			200 Ω	¼ W		5%
R311	321-0273-30			6.81 kΩ	⅛ W	Prec	1%
R313	321-0306-30			15 kΩ	⅛ W	Prec	1%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R314	321-0362-30			57.6 kΩ	1/8 W	Prec	1%
R316	315-0102-01			1 kΩ	1/4 W		5%
R321	315-0152-01			1.5 kΩ	1/4 W		5%
R323	315-0222-02			2.2 kΩ	1/4 W		5%
R324	315-0222-02			2.2 kΩ	1/4 W		5%
R326	315-0101-01			100 Ω	1/4 W		5%
R328	315-0682-01			6.8 kΩ	1/4 W		5%
R330A	309-0095-00			10 MΩ	1/2 W	Prec	1%
R330B	309-0087-00			5 MΩ	1/2 W	Prec	1%
R330C	322-0481-00			1 MΩ	1/4 W	Prec	1%
R330D	322-0481-00			1 MΩ	1/4 W	Prec	1%
R330E	322-0481-00			1 MΩ	1/4 W	Prec	1%
R330F	321-0648-00			500 kΩ	1/8 W	Prec	1/2%
R330G	321-0414-30			200 kΩ	1/8 W	Prec	1%
R330H	321-0385-30			100 kΩ	1/8 W	Prec	1%
R330J	321-0356-30			49.9 kΩ	1/8 W	Prec	1%
R333	315-0103-02			10 kΩ	1/4 W		5%
R334A R334B	311-0688-00	300000	300251	20 kΩ 200 kΩ Var			
R334A R334B	311-0688-01	300252		20 kΩ 200 kΩ Var			
R340A	315-0512-01			5.1 kΩ	1/4 W		5%
R342	315-0913-01			91 kΩ	1/4 W		5%
R344	315-0333-01			33 kΩ	1/4 W		5%
R346	321-0247-30			3.65 kΩ	1/8 W	Prec	1%
R347	311-0633-00			5 kΩ, Var			
R351	315-0104-02			100 kΩ	1/4 W		5%
R353	315-0204-01			200 kΩ	1/4 W		5%
R355	315-0472-01			4.7 kΩ	1/4 W		5%
R357	315-0151-01			150 Ω	1/4 W		5%
R359	315-0102-01			1 kΩ	1/4 W		5%
R363	315-0473-01			47 kΩ	1/4 W		5%
R365	315-0752-01			7.5 kΩ	1/4 W		5%
R366	315-0202-01			2 kΩ	1/4 W		5%
R367	315-0103-02			10 kΩ	1/4 W		5%
R369	315-0394-01			390 kΩ	1/4 W		5%
R372	315-0202-01			2 kΩ	1/4 W		5%
R401	311-0607-00			10 kΩ, Var			
R402	321-0338-30			32.4 kΩ	1/8 W	Prec	1%
R404A	301-0915-00			9.1 MΩ	1/2 W		5%
R404B	301-0435-00			4.3 MΩ	1/2 W		5%
R404C	301-0245-00			2.4 MΩ	1/2 W		5%
R404D	301-0185-00			1.8 MΩ	1/2 W		5%
R404E	301-0135-00			1.3 MΩ	1/2 W		5%
R405	315-0623-01			62 kΩ	1/4 W		5%
R407	315-0134-02			130 kΩ	1/4 W		5%
R409A R409B	311-0691-00			2 X 20 kΩ, Var			

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R410	315-0273-01			27 kΩ	¼ W		5%
R411	315-0104-02			100 kΩ	¼ W		5%
R412	315-0153-02			15 kΩ	¼ W		5%
R414	315-0472-01			4.7 kΩ	¼ W		5%
R416	315-0392-01			3.9 kΩ	¼ W		5%
R420	315-0101-01			100 Ω	¼ W		5%
R422	315-0302-01			3 kΩ	¼ W		5%
R424	315-0102-01			1 kΩ	¼ W		5%
R430	322-0481-00			1 MΩ	¼ W	Prec	1%
R431	321-0354-30			47.5 kΩ	⅛ W	Prec	1%
R433	311-0633-00			5 kΩ, Var			
R437	315-0272-02			2.7 kΩ	¼ W		5%
R438	315-0472-01			4.7 kΩ	¼ W		5%
R439	311-0644-00			20 kΩ, Var			
R441	315-0153-02			15 kΩ	¼ W		5%
R443	316-0275-01			2.7 MΩ	¼ W		
R444	315-0393-01			39 kΩ	¼ W		5%
R446	315-0915-01			9.1 MΩ	¼ W		5%
R450	315-0433-01			43 kΩ	¼ W		5%
R451	315-0472-01			4.7 kΩ	¼ W		5%
R452	315-0222-02			2.2 kΩ	¼ W		5%
R454	322-0481-00			1 MΩ	¼ W	Prec	1%
R455	321-0338-30			32.4 kΩ	⅛ W	Prec	1%
R457	322-0481-00			1 MΩ	¼ W	Prec	1%
R491	315-0100-01			10 Ω	¼ W		5%
R493	315-0201-01			200 Ω	¼ W		5%
R503	321-0308-30			15.8 kΩ	⅛ W	Prec	1%
R504	321-0388-30			107 kΩ	⅛ W	Prec	1%
R506	315-0105-01			1 MΩ	¼ W		5%
R510	315-0153-02			15 kΩ	¼ W		5%
R512	315-0123-01			12 kΩ	¼ W		5%
R513	311-0614-00			30 kΩ, Var			
R514	321-0396-30			130 kΩ	⅛ W	Prec	1%
R515	301-0514-00	300000	300030	510 kΩ	½ W		5%
R515	301-0564-00	300031		560 kΩ	½ W		5%
R516	315-0103-02			10 kΩ	¼ W		5%
R517	315-0102-01			1 kΩ	¼ W		5%
R518	315-0271-01			270 Ω	¼ W		5%
R519	315-0102-01			1 kΩ	¼ W		5%
R523	315-0562-01			5.6 kΩ	¼ W		5%
R524	315-0122-01			1.2 kΩ	¼ W		5%
R526	315-0102-01			1 kΩ	¼ W		5%
R528	307-0106-00			4.7 Ω	¼ W		5%
R531	315-0471-02			470 Ω	¼ W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R534	323-0498-00			1.5 MΩ	½ W	Prec	1%
R535	321-0452-00			499 kΩ	⅛ W	Prec	1%
R541	315-0102-01			1 kΩ	¼ W		5%
R547	315-0202-01			2 kΩ	¼ W		5%
R551	321-0378-30			84.5 kΩ	⅛ W	Prec	1%
R552	311-0644-00			20 kΩ, Var			
R553	321-0351-30			44.2 kΩ	⅛ W	Prec	1%
R555	321-0348-30			41.2 kΩ	⅛ W	Prec	1%
R556	315-0474-01			470 kΩ	¼ W		5%
R557	315-0473-01			47 kΩ	¼ W		5%
R558	315-0472-01			4.7 kΩ	¼ W		5%
R561	315-0102-01			1 kΩ	¼ W		5%
R562	315-0472-01			4.7 kΩ	¼ W		5%
R563	315-0470-02			47 Ω	¼ W		5%
R564	321-0334-30			29.4 kΩ	⅛ W	Prec	1%
R565	321-0300-30			13 kΩ	⅛ W	Prec	1%
R566	311-0633-00			5 kΩ, Var			
R567	321-0331-30			27.4 kΩ	⅛ W	Prec	1%
R568	315-0472-01			4.7 kΩ	¼ W		5%
R570	315-0221-01			220 Ω	¼ W		5%
R572	315-0332-02			3.3 kΩ	¼ W		5%
R580	301-0106-00			10 MΩ	½ W		5%
R581	311-0690-00			5 MΩ, Var			
R582	301-0106-00			10 MΩ	½ W		5%
R583	311-0698-00			1 MΩ, Var			
R584	315-0474-01	300000	300372	470 kΩ	Selected (nominal value)		
R584	315-0105-01	300373		1 MΩ	Selected (nominal value)		
R585	311-0690-00			5 MΩ, Var			
R587	301-0226-00			22 MΩ	½ W		5%
R590	315-0470-02			47 Ω	¼ W		5%
R591	315-0470-02			47 Ω	¼ W		5%
R592	311-0607-00			10 kΩ, Var			
R593	311-0660-00			200 kΩ, Var			
R594	315-0204-01			200 kΩ	¼ W		5%
R596	315-0474-01			470 kΩ	¼ W		5%
R597	311-0606-00			500 kΩ, Var			
R598	315-0823-01			82 kΩ	¼ W		5%

Switches

Ckt. No.	Unwired or Wired	Part No.	Eff	Disc	Description	
SW21		260-0621-01			Lever	INPUT AC GND DC
SW25	Wired	*262-0820-00			Rotary	VOLTS/DIV
SW25		260-0885-00			Rotary	VOLTS/DIV
SW45		260-0904-00			Slide	X10 VERT GAIN
SW201		260-0888-00	300000	300377	Lever	TRIG/HORIZ COUPLING
SW201		260-0888-01	300378		Lever	TRIG/HORIZ COUPLING

Switches *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
	Unwired or Wired				
SW205	260-0905-00			Slide	ATTEN 1 X 10 X
SW246	Wired *262-0821-00			Rotary	TRIGGER
SW246	260-0886-00			Rotary	TRIGGER
SW335	Wired *262-0822-00			Rotary	TIME/DIV
SW335	260-0887-00			Rotary	TIME/DIV
SW435	260-0904-00			Slide	X10 HORIZ MAG
SW501	260-0903-00			Slide	POWER ON-OFF

Transformers

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
T525	*120-0505-00	300000	300507	Toroid
T525	*120-0505-01	300508		Toroid
T538	*120-0504-00			H.V. Power

Electron Tube

Ckt. No.	Tektronix Part No.	Eff	Disc	Description
V590	*154-0519-00			CRT T3230

POWER PACK

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
	*016-0119-00	300000	302458			Complete Power Pack	
	*016-0119-02	302459				Complete Power Pack	

Capacitors

C605	290-0287-00	47 μF	Elect.	25 V	
C623	283-0003-01	0.01 μF	Cer	150 V	
C636	290-0114-01	47 μF	Elect.	6 V	

Semiconductor Device, Diodes

D605	*152-0107-00	Silicon	Replaceable by 1N647
D610A,B,C,D(4)	*152-0107-00	Silicon	Replaceable by 1N647
D637	152-0008-00	Germanium	
D638	152-0008-00	Germanium	
D649	152-0166-00	Zener	1N753A 400 mW 6.2 V 5%

Fuses

F601	Use 159-0080-00	1/5A	Slo-Blo 115 V operation
F601	Use 159-0074-00	1/10A	Slo-Blo 230 V operation

Connectors

P601	131-0552-00	Motor Base
J611	136-0139-00	Socket, Banana Jack Assy
J612	136-0140-00	Socket, Banana Jack Assy

Inductor

L611A,B	*108-0488-00	150 μH

Transistors

Q617	151-0229-00	Silicon	2SD28
Q620	*151-0219-00	Silicon	Replaceable by 2N4250
Q621	151-0224-00	Silicon	2N3692
Q634	*151-0219-00	Silicon	Replaceable by 2N4250
Q636	*151-0219-00	Silicon	Replaceable by 2N4250

Resistors

R605	315-0472-01	4.7 kΩ	¼ W		5%
R615	308-0463-00	0.3 Ω	3 W	WW	1%
R619	315-0100-01	10 Ω	¼ W		5%
R620	315-0102-01	1 kΩ	¼ W		5%
R623	315-0471-02	470 Ω	¼ W		5%

Resistors *(cont)*

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
R630	315-0272-02			2.7 kΩ	¼ W		5%
R633	321-0445-00			422 kΩ	⅛ W	Prec	1%
R635	315-0752-01			7.5 kΩ	¼ W		5%
R637	315-0102-01			1 kΩ	¼ W		5%
R638	315-0102-01			1 kΩ	¼ W		5%
R639	315-0152-01			1.5 kΩ	¼ W		5%
R641	315-0272-02			2.7 kΩ	¼ W		5%
R643	321-0341-30			34.8 kΩ	⅛ W	Prec	1%
R644	311-0635-00			1 kΩ, Var			

Switches

	Unwired or Wired		
SW612	260-0902-00	Slide	EXT DC TRICKLE CHG FULL CHG

Transformers

T601	*120-0503-00	L.V. Power

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear either on the back of the diagrams or on pullout pages immediately following the diagrams of the instruction manual.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the Description column.

Assembly and/or Component
  Detail Part of Assembly and/or Component
  mounting hardware for Detail Part
    Parts of Detail Part
    mounting hardware for Parts of Detail Part
mounting hardware for Assembly and/or Component

Mounting hardware always appears in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation.

Mounting hardware must be purchased separately, unless otherwise specified.

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial or model number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

ABBREVIATIONS AND SYMBOLS

For an explanation of the abbreviations and symbols used in this section, please refer to the page immediately preceding the Electrical Parts List in this instruction manual.

INDEX OF MECHANICAL PARTS LIST ILLUSTRATIONS

(Located behind diagrams)

SECTION 8
MECHANICAL PARTS LIST

FIG. 1 MECHANICAL PARTS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-1	366-1031-00			1	KNOB, red—VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0153-00			1	SCREW, set, 5-40 x 1/8 inch, HSS
-2	366-1037-00			1	KNOB, gray—VOLTS/DIV
	- - - - - -			-	knob includes:
	213-0153-00			2	SCREW, set, 5-40 x 1/8 inch, HSS
-3	262-0820-00			1	SWITCH, wired—VOLTS/DIV
	- - - - - -			-	switch includes:
	260-0885-00			1	SWITCH, unwired
	670-0575-00			1	ASSEMBLY, circuit board—attenuator
	- - - - - -			-	assembly includes:
-4	388-0909-00			1	BOARD, circuit
	- - - - - -			-	mounting hardware: (not included w/board)
-5	211-0079-00			4	SCREW, 2-56 x 3/16 inch, PHS
-6	210-0001-00			4	LOCKWASHER, #2 internal
-7	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-8	- - - - - -			1	WASHER, flat
-9	- - - - - -			1	NUT (metric)
	- - - - - -			-	mounting hardware: (not included w/resistor)
-10	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
-11	214-1001-00			1	SPRING, detent
	376-0069-00			1	COUPLING, shaft extension, 1/8 to 0.80 inch
	- - - - - -			-	coupling includes:
-12	354-0319-00			1	RING, coupling (w/detent notch)
-13	376-0046-00			1	COUPLING, plastic
-14	354-0251-00			1	RING, coupling
	213-0048-00			4	SCREW, set, 4-40 x 1/8 inch, HSS
-15	384-0683-00			1	SHAFT, extension
	- - - - - -			-	mounting hardware: (not included w/switch)
-16	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
-17	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-18	210-0590-00			1	NUT, hex., 3/8-32 x 7/16 inch
-19	366-1031-00			1	KNOB, red—VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0153-00			1	SCREW, set, 5-40 x 1/8 inch, HSS
-20	366-1037-00			1	KNOB, gray—TIME/DIV
	- - - - - -			-	knob includes:
	213-0153-00			2	SCREW, set, 5-40 x 1/8 inch, HSS

FIG. 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-21	262-0822-00			1	SWITCH, wired—TIME/DIV
	- - - - - -			-	switch includes:
	260-0887-00			1	SWITCH, unwired
-22	337-0989-00			1	SHIELD, switch, flat
-23	337-0990-00			1	SHIELD, switch, angle
	- - - - - -			-	mounting hardware: (not included w/shield)
	210-0054-00			2	LOCKWASHER, #4 split
-24	210-0406-00			2	NUT, hex., 4-40 x $^3/_{16}$ inch
-25	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
-26	- - - - - -			1	WASHER, flat
-27	- - - - - -			1	NUT (metric)
	- - - - - -			-	mounting hardware: (not included w/resistor)
-28	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
-29	214-1001-00			1	SPRING, detent
	376-0070-00			1	COUPLING, shaft extension, $^1/_8$ to $^1/_8$ inch
	- - - - - -			-	coupling includes:
-30	354-0319-00			1	RING, coupling (w/detent notch)
-31	376-0049-00			1	COUPLING, plastic
-32	354-0251-00			1	RING, coupling
	213-0048-00			4	SCREW, set, 4-40 x $^1/_8$ inch, HSS
-33	384-0682-00			1	SHAFT, extension
	- - - - - -			-	mounting hardware: (not included w/switch)
-34	210-0840-00			1	WASHER, flat, 0.390 ID x $^9/_{16}$ inch OD
-35	210-0840-00			1	WASHER, flat, 0.390 ID x $^9/_{16}$ inch OD
-36	210-0590-00			1	NUT, hex., $^3/_8$-32 x $^7/_{16}$ inch
-37	366-0456-00			1	KNOB, thumbwheel—FOCUS
	- - - - - -			-	knob includes:
	213-0048-00			2	SCREW, set, 4-40 x $^1/_8$ inch, HSS
-38	366-0456-00			1	KNOB, thumbwheel—INTENSITY
	- - - - - -			-	knob includes:
	213-0048-00			2	SCREW, set, 4-40 x $^1/_8$ inch, HSS
-39	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
-40	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch
-41	200-0799-00			2	COVER, variable resistor
-42	366-1039-00			1	KNOB, charcoal—TRIGGER
	- - - - - -			-	knob includes:
	213-0153-00			2	SCREW, set, 5-40 x $^1/_8$ inch, HSS
-43	262-0821-00			1	SWITCH, wired—TRIGGER
	- - - - - -			-	switch includes:
	260-0886-00			1	SWITCH, unwired
-44	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	resistor includes:
	- - - - - -			-	WASHER, flat
-45	- - - - - -			1	NUT (metric)
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD

FIG. 1 MECHANICAL PARTS (*cont*)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-	376-0051-00			1	COUPLING, shaft extension, 1/8 to 1/8 inch
	- - - - - -			-	coupling includes:
-46	354-0251-00			2	RING, coupling
-47	376-0049-00			1	COUPLING, plastic
	213-0048-00			4	SCREW, set, 4-40 x 1/8 inch, HSS
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0012-00			1	LOCKWASHER, internal, 3/8 ID x 1/2 inch OD
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
-48	220-0495-00			1	NUT, hex., 3/8-32 x 7/16 inch x 1/16 inch thick
-49	366-0215-02			1	KNOB, lever, gray—INT TRIG-EXT TRIG
-50	260-0888-00	300000	300377	1	SWITCH, lever—INT TRIG-EXT TRIG
	260-0888-01	300378		1	SWITCH, lever—INT TRIG-EXT TRIG
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0004-00			2	LOCKWASHER, internal, #4
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-51	366-0215-02			1	KNOB, lever, gray—INPUT
-52	260-0621-01			1	SWITCH, lever—INPUT
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0004-00			2	LOCKWASHER, internal, #4
-53	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-54	260-0903-00			1	SWITCH, slide—POWER
	- - - - - -			-	mounting hardware: (not included w/switch)
-55	211-0101-00			2	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-56	214-0992-00			1	INDICATOR, switch position
-57	366-1038-00			1	KNOB, gray w/yellow band—POSITION-10X VERT GAIN
	- - - - - -			-	knob includes:
	213-0153-00			1	SCREW, set, 5-40 x 1/8 inch, HSS
-58	366-1038-00			1	KNOB, gray w/yellow band—POSITION-10X HORIZ MAG
	- - - - - -			-	knob includes:
	213-0153-00			1	SCREW, set, 5-40 x 1/8 inch, HSS
-59	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-60	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0259-00	X300031	300846X	1	LUG, solder, #2
-61	358-0331-00			1	BUSHING, 0.418 inch OD, w/5.8 MM x 0.75 MM threads
-62	407-0413-00	300000	300330	1	BRACKET, double angle
	407-0413-01	300331		1	BRACKET
-63	129-0141-00			1	POST, non metallic, 0.250 OD x 0.300 inches long
-64	407-0408-00			1	BRACKET, slide switch
	- - - - - -			-	mounting hardware: (not included w/bracket)
	210-0004-00			2	LOCKWASHER, internal, #4
-65	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-66	260-0904-00			1	SWITCH, slide—10X HORIZ MAG
	- - - - - -			-	mounting hardware: (not included w/switch)
-67	211-0079-00			2	SCREW, 2-56 x 3/16 inch, PHS
-68	260-0904-00			1	SWITCH, slide—10X VERT GAIN
	- - - - - -			-	mounting hardware: (not included w/switch)
-69	211-0079-00			2	SCREW, 2-56 x 3/16 inch, PHS
	337-0997-00			1	SHIELD, slide switch (not shown)

FIG. 1 MECHANICAL PARTS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-70	352-0084-01			1	HOLDER, neon
-71	378-0541-00			1	LENS, indicator light
-72	200-0609-00			1	COVER, cap, neon holder
-73	337-0983-01			1	SHIELD, CRT
	- - - - - -			-	mounting hardware: (not included w/shield)
-74	211-0038-00			1	SCREW, 4-40 x $^1/_4$ inch, 100° csk, FHS
-75	210-0586-00			1	NUT, keps, 4-40 x $^1/_4$ inch
	- - - - - -			-	CATHODE RAY TUBE
	- - - - - -			-	tube includes:
-76	331-0193-00			1	MASK, CRT
-77	426-0402-00			1	FRAME-FILTER ASSEMBLY, light
	- - - - - -			-	mounting hardware: (not included w/assembly)
	214-0986-00			1	SPRING, flat, pre-bent (not shown)
-78	136-0266-01			1	SOCKET, CRT, 12 pin, w/wiring harness
-79	386-1316-00			1	SUPPORT, CRT
-80	348-0003-00			1	GROMMET, rubber, $^5/_{16}$ inch diameter
	344-0176-00			1	CLIP, ground (not shown)
	210-1001-00			1	WASHER, flat, 0.119 ID x $^3/_8$ inch OD (not shown)
-81	441-0762-00			1	CHASSIS, main
	- - - - - -			-	mounting hardware: (not included w/chassis)
-82	210-0586-00			4	NUT, keps, 4-40 x $^1/_4$ inch
-83	348-0004-00			1	GROMMET, rubber, $^3/_8$ inch diameter
-84	348-0031-00			1	GROMMET, plastic, $^5/_{32}$ inch diameter
-85	343-0042-00			1	CLAMP, cable, half, $^5/_{16}$ inch diameter
	- - - - - -			-	mounting hardware: (not included w/clamp)
	210-0801-00			1	WASHER, flat, 0.140 ID x 0.281 inch OD
-86	210-0586-00			1	NUT, keps, 4-40 x $^1/_4$ inch
-87	670-0576-00			1	ASSEMBLY, circuit board—MAIN
	- - - - - -			-	assembly includes:
	388-0910-00			1	BOARD, circuit
-88	136-0220-00			27	SOCKET, transistor, 3 pin
-89	136-0183-00			13	SOCKET, transistor, 3 pin
-90	136-0235-00			5	SOCKET, transistor, dual
-91	337-1005-00			1	SHIELD, electrical
-92	337-0975-00			2	SHIELD, electrical
-93	337-1004-00			1	SHIELD, electrical (bent)
	- - - - - -			-	mounting hardware: (not included w/assembly)
-94	211-0116-00			5	SCREW, sems, 4-40 x $^5/_{16}$ inch, PHB
-95	670-0578-00			1	ASSEMBLY, circuit board—POWER SUPPLY
	- - - - - -			-	assembly includes:
	388-0912-00			1	BOARD, circuit
	136-0183-00			2	SOCKET, transistor, 3 pin
	346-0032-00			4	STRAP, mousetail (not shown)
-96	352-0131-00			1	HOLDER, toroid
	- - - - - -			-	mounting hardware: (not included w/holder)
-97	361-0007-00			1	SPACER, plastic, 0.188 inch long
	- - - - - -			-	mounting hardware: (not included w assembly)
-98	361-0173-00			3	SPACER, sleeve
-99	129-0142-00			3	POST, non metallic, $1^1/_2$ inches long
	210-0004-00			2	LOCKWASHER, internal, #4

FIG. 1 MECHANICAL PARTS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-100	670-0579-00			1	ASSEMBLY, circuit board—POWER REGULATOR
	- - - - - -			-	assembly includes:
	388-0913-00			1	BOARD, circuit
-101	136-0220-00			8	SOCKET, transistor, 3 pin
-102	352-0100-00			3	HOLDER, variable resistor
	- - - - - -			-	mounting hardware for each: (not included w/holder)
-103	361-0008-00			1	SPACER, plastic, 0.281 inch long
-104	214-0283-00			2	SPRING
	- - - - - -			-	mounting hardware: (not included w/assembly)
-105	211-0008-00			3	SCREW, 4-40 x 1/4 inch, PHS
-106	337-1006-00			1	SHIELD, electrical, angle (co-netic foil)
	016-0119-00			1	ASSEMBLY, power pack
	- - - - - -			-	assembly includes:
-107	670-0577-00			1	ASSEMBLY, circuit board—BATTERY CHARGER
	- - - - - -			-	assembly includes:
	388-0911-00			1	BOARD, circuit
-108	136-0220-00			4	SOCKET, transistor, 3 pin
-109	214-0506-00			3	CONNECTOR, square pin
-110	214-0507-00			4	CONNECTOR, square pin (angled)
	- - - - - -			-	mounting hardware: (not included w/assembly)
-111	210-0994-00			3	WASHER, flat, 0.125 ID x 0.250 inch OD
-112	210-0004-00			3	LOCKWASHER, internal, #4
	210-0201-00			1	LUG, solder, SE #4
-113	210-0406-00			6	NUT, hex., 4-40 x 3/16 inch
-114	343-0119-00			1	CLAMP, cable, 3/32 inch
-115	386-1328-00			1	PLATE, battery box, inside
	214-1059-00			1	INSULATOR
	- - - - - -			-	mounting hardware: (not included w/plate)
-116	211-0008-00			5	SCREW, 4-40 x 1/4 inch, PHS
-117	386-1327-00			1	PLATE, battery box, outside
	- - - - - -			-	mounting hardware: (not included w/plate)
-118	211-0101-00			6	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-119	343-0148-00			1	CLAMP, battery retaining (lower)
	343-0148-01			1	CLAMP, battery retaining (upper)
-120	105-0063-00			2	STRIKE, post
-121	211-0025-00			2	SCREW, 4-40 x 3/8 inch, 100° csk, FHS
	146-0012-00			1	BATTERY SET, spot-welded together and taped
	- - - - - -			-	battery set includes:
-122	146-0011-00			6	BATTERY, ni-cad cell, 1.8 inch A.H.
-123	214-1013-00	300000	300299	2	INSULATOR, plate, foam
	214-1013-01	300300		2	INSULATOR, plate
-124	136-0140-00			1	SOCKET, banana jack, charcoal
	- - - - - -			-	mounting hardware: (not included w/socket)
-125	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-126	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch
-127	136-0139-00			1	SOCKET, banana jack, red
	- - - - - -			-	mounting hardware: (not included w/socket)
-128	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-129	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch

FIG. 1 MECHANICAL PARTS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-130	352-0132-00			1	HOLDER, Tip jack
	- - - - - -			-	mounting hardware: (not included w/holder)
-131	213-0107-00			1	SCREW, thread forming, 4-40 x 1/4 inch, 100° csk, FHS
-132	131-0552-00			1	CONNECTOR, with fuse holder
	- - - - - -			-	mounting hardware: (not included w/connector)
-133	211-0101-00			2	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-134	200-0813-00			1	COVER, fuse
-135	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
-136	211-0021-00	300000	300160	2	SCREW, 4-40 x 1 1/4 inches, RHS
	211-0153-00	300161		2	SCREW, 4-40 x 1 9/32 inches, RHS
	210-0906-00			3	WASHER, fiber, 1/8 ID x 13/64 inch OD
	210-0201-00			1	LUG, solder, SE #4
-137	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
-138	260-0902-00			1	SWITCH, slide—EXT DC TRICKLE CHG FULL CHG
	- - - - - -			-	mounting hardware: (not included w/switch)
-139	211-0119-00			2	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-140	- - - - - -			1	TRANSISTOR
	- - - - - -			-	mounting hardware: (not included w/transistor)
-141	214-1025-00			1	INSULATOR, mica
-142	211-0510-00			2	SCREW, 6-32 x 3/8 inch, PHS
-143	210-0811-00			2	WASHER, fiber, shouldered, #6
-144	210-0802-00			2	WASHER, flat, 0.150 ID x 5/16 inch OD
-145	210-0202-00			1	LUG, solder, SE #6
-146	210-0006-00			1	LOCKWASHER, internal, #6
-147	210-0407-00			2	NUT, hex., 6-32 x 1/4 inch
-148	214-0993-00			1	HEAT SINK, transistor
-149	348-0055-00			1	GROMMET, plastic, 1/4 inch diameter
	348-0031-00			1	GROMMET, plastic, 5/32 inch diameter (not shown)
-150	179-1207-00			1	WIRING HARNESS, battery
-151	129-0135-00			2	POST, metallic, 4.31 inches long
	- - - - - -			-	mounting hardware for each: (not included w/post)
-152	211-0101-00			1	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-153	211-0038-00			1	SCREW, 4-40 x 5/16 inch, 100° csk, FHS
-154	129-0136-00			1	POST, metallic, 3.120 inches long
	- - - - - -			-	mounting hardware: (not included w/post)
-155	211-0038-00			1	SCREW, 4-40 x 5/16 inch, 100° csk, FHS
-156	129-0136-00	300000	300030	1	POST, metallic, 3.120 inches long
	129-0136-01	300031		1	POST, metallic, 3.120 inches long
	- - - - - -			-	mounting hardware: (not included w/post)
-157	211-0101-00			1	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
	211-0038-00			1	SCREW, 4-40 x 5/16 inch, 100° csk, FHS

FIG. 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Part No. Tektronix	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-158	105-0062-01	300000	300579	1	CATCH, friction
	105-0062-02	300580		1	CATCH, friction
	- - - - - -			-	mounting hardware: (not included w/catch)
-159	210-0948-00			1	WASHER, flat, 0.166 ID x 0.216 inch OD
	210-0802-00			1	WASHER, flat, 0.150 ID x $^5/_{16}$ inch OD
	210-0994-00			1	WASHER, flat, 0.125 ID x 0.250 inch OD
-160	211-0140-00			1	SCREW, shoulder, 4-40 x 0.775 inch, HHS
-161	441-0763-00			1	CHASSIS, support, shield
	- - - - - -			-	mounting hardware: (not included w/chassis)
-162	211-0101-00			1	SCREW, 4-40 x $^1/_4$ inch, 100° csk, FHS
-163	210-0801-00			1	WASHER, flat, 0.125 ID x 0.250 inch OD
-164	210-0004-00			1	LOCKWASHER, internal, #4
-165	210-0406-00			1	NUT, hex., 4-40 x $^3/_{16}$ inch
-166	210-0586-00			4	NUT, keps, 4-40 x $^1/_4$ inch
-167	337-0974-00			1	SHIELD, electrical, high voltage box
	- - - - - -			-	mounting hardware: (not included w/shield)
-168	211-0101-00			1	SCREW, 4-40 x $^1/_4$ inch, 100° csk, FHS
-169	210-0801-00			1	WASHER, flat, 0.125 ID x 0.250 inch OD
-170	210-0004-00			1	LOCKWASHER, internal, #4
-171	210-0406-00			1	NUT, hex., 4-40 x $^3/_{16}$ inch
-172	210-0586-00			3	NUT, keps, 4-40 x $^1/_4$ inch
-173	348-0067-00			1	GROMMET, plastic, $^5/_{16}$ inch diameter
-174	348-0055-00			2	GROMMET, plastic, $^1/_4$ inch diameter
-175	337-0984-00			1	SHIELD, electrical attenuator
	- - - - - -			-	mounting hardware: (not included w/shield)
-176	211-0008-00			1	SCREW, 4-40 x $^1/_4$ inch, PHS
-177	344-0124-00			1	CLIP, retainer, capacitor
	- - - - - -			-	mounting hardware: (not included w/clip)
-178	213-0120-00			1	SCREW, thread forming, 2-32 x $^1/_4$ inch, PHS
-179	352-0135-00			1	HOLDER, spare fuses
	- - - - - -			-	mounting hardware: (not included w/holder)
-180	361-0007-00			2	SPACER, plastic, 0.188 inch long
-181	386-1314-00	300000	300329	1	PLATE, sub-panel, side
	386-1314-01	300300		1	PLATE, sub-panel, side
	- - - - - -			-	mounting hardware: (not included w/bracket)
-182	210-0004-00			1	LOCKWASHER, internal, #4
-183	210-0406-00			1	NUT, hex., 4-40 x $^3/_{16}$ inch
-184	211-0008-00			1	SCREW, 4-40 x $^1/_4$ inch, PHS
-185	333-1028-01			1	PANEL, side
-186	260-0905-00			1	SWITCH, slide—ATTEN
	- - - - - -			-	mounting hardware: (not included w/switch)
-187	211-0073-00			2	SCREW, 2-56 x $^7/_{32}$ inch, 82° csk, FHS

FIG. 1 MECHANICAL PARTS (cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-188	131-0106-00			1	CONNECTOR, coaxial, 1 contact, BNC (with hardware)
	- - - - - -			-	mounting hardware: (not included w/connector)
-189	210-0255-00			1	LUG, solder, 3/8 inch
-190	136-0140-00			2	SOCKET, banana jack, charcoal
	- - - - - -			-	mounting hardware for each: (not included w/socket)
-191	210-0895-00			1	WASHER, insulating
-192	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch, OD, SE
-193	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch
-194	131-0274-00			1	CONNECTOR, coaxial, insulated, 1 contact, BNC (with hardware)
-195	129-0103-00			1	ASSEMBLY, binding post
	- - - - - -			-	assembly includes:
	129-0077-00			1	POST, binding
	200-0103-00			1	CAP, binding post
	- - - - - -			-	mounting hardware: (not included w/post)
-196	210-0223-00			1	LUG, solder, 1/4 ID x 7/16 inch OD, SE
-197	210-0455-00			1	NUT, hex., 1/4-28 x 3/8 inch
-198	386-1317-00			1	PLATE, sub-panel, rear (inner)
-199	213-0171-00	300000	300507	1	THUMBSCREW, plastic
	213-0215-00	300508		1	THUMBSCREW, plastic
-200	333-1027-01			1	PANEL, front
-201	386-1313-01	300000	300348	1	PLATE, front sub-panel
	386-1313-02	300349		1	PLATE, front sub-panel
-202	337-0973-00			1	SHIELD, voltage
	- - - - - -			-	mounting hardware: (not included w/shield)
-203	211-0101-00			2	SCREW, 4-40 x 1/4 inch, 100° csk, FHS
-204	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
-205	211-0008-00			1	SCREW, 4-40 x 1/4 inch, PHS
-206	179-1210-00			1	WIRING HARNESS, main
-207	179-1208-00			1	WIRING HARNESS, voltage
-208	179-1209-00			1	WIRING HARNESS, switch
-209	348-0031-00			1	GROMMET, 5/32 inch diameter

FIG. 2 CABINET

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-1	390-0026-00			1	CABINET
-2	386-1315-01			1	SUB-PANEL, rear, outer
-3	386-1318-00			1	PANEL, rear
-4	348-0138-00			8	FOOT
-5	367-0084-00			1	HANDLE
	- - - - - -			-	handle includes:
-6	334-1171-00			1	TAG, identification
-7	129-0148-00	300000	300150	2	POST, metallic, 6-32 tap
	129-0148-02	300151		2	POST, metallic, 6-32 tap
-8	386-1339-00			2	PLATE, brake, friction, inner
-9	386-1331-00			2	PLATE, brake, friction, outer
-10	210-1053-00			4	WASHER, spring tension
-11	200-0819-00			2	COVER, handle, brake
-12	132-0084-00			2	SPACER, plastic, 0.450 dia x 0.050 inch long
-13	213-0179-00	300000	300150	2	SCREW, cap, 6-32 threads
	213-0179-02	300151		2	SCREW, cap, 6-32 threads
-14	213-0170-00			1	THUMBSCREW, cabinet
	- - - - - -			-	mounting hardware: (not included w/thumbscrew)
	354-0324-00			1	RING, retaining (not shown)

DIAGRAMS
SECTION 9

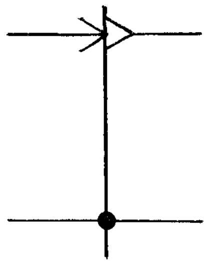
The following symbols are used on the diagrams:

Screwdriver adjustment

Externally accessible control or connector.

Clockwise control rotation in direction of arrow.

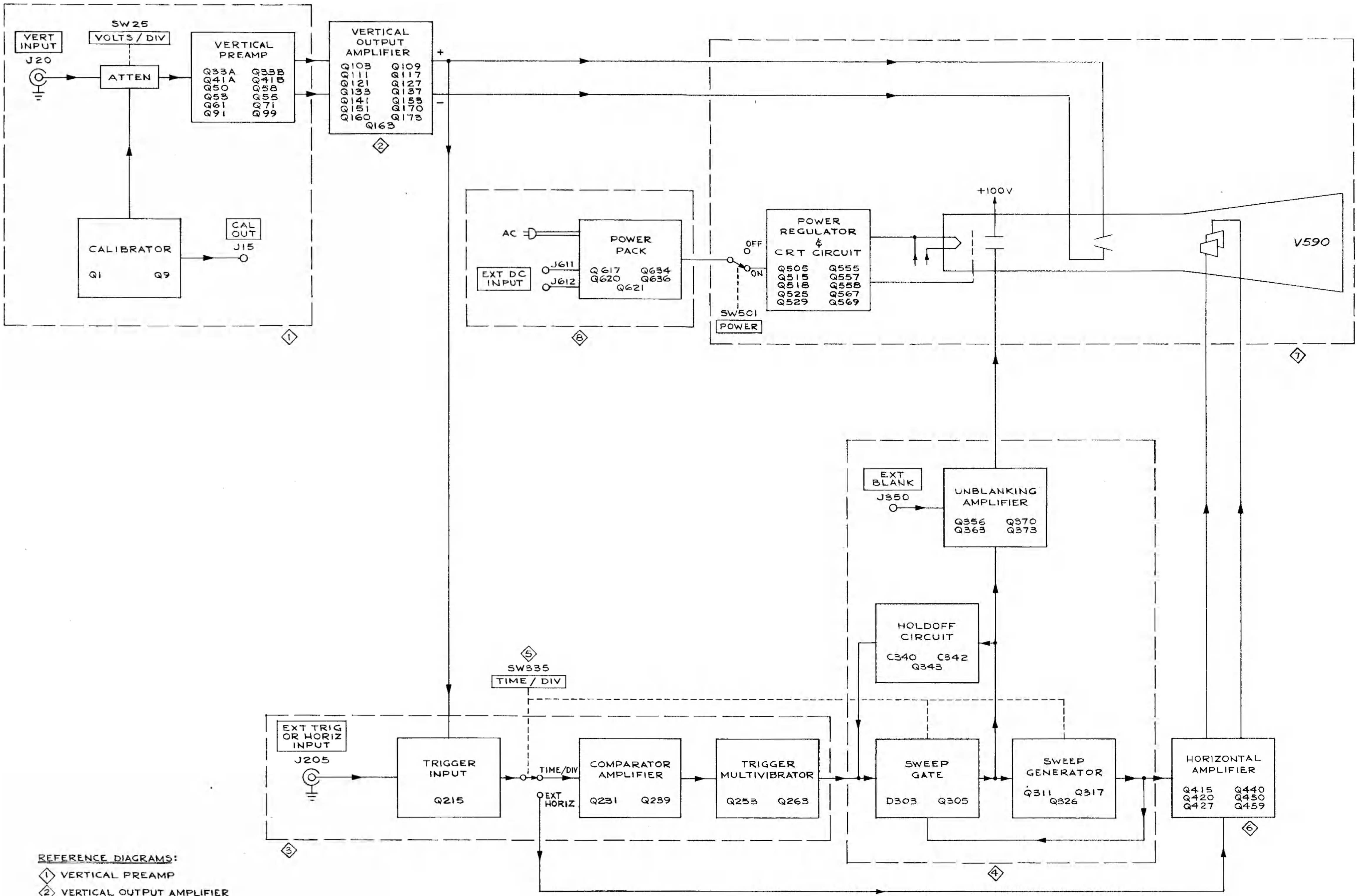
Refer to indicated diagram.



Connection to circuit board made with pin connector.

Blue line encloses components located on circuit board.

Connection soldered to circuit board.



REFERENCE DIAGRAMS:

1. VERTICAL PREAMP
2. VERTICAL OUTPUT AMPLIFIER
3. TRIGGER GENERATOR
4. SWEEP GENERATOR
5. TIMING SWITCH
6. HORIZONTAL AMPLIFIER
7. POWER REGULATOR & CRT CIRCUIT
8. POWER PACK

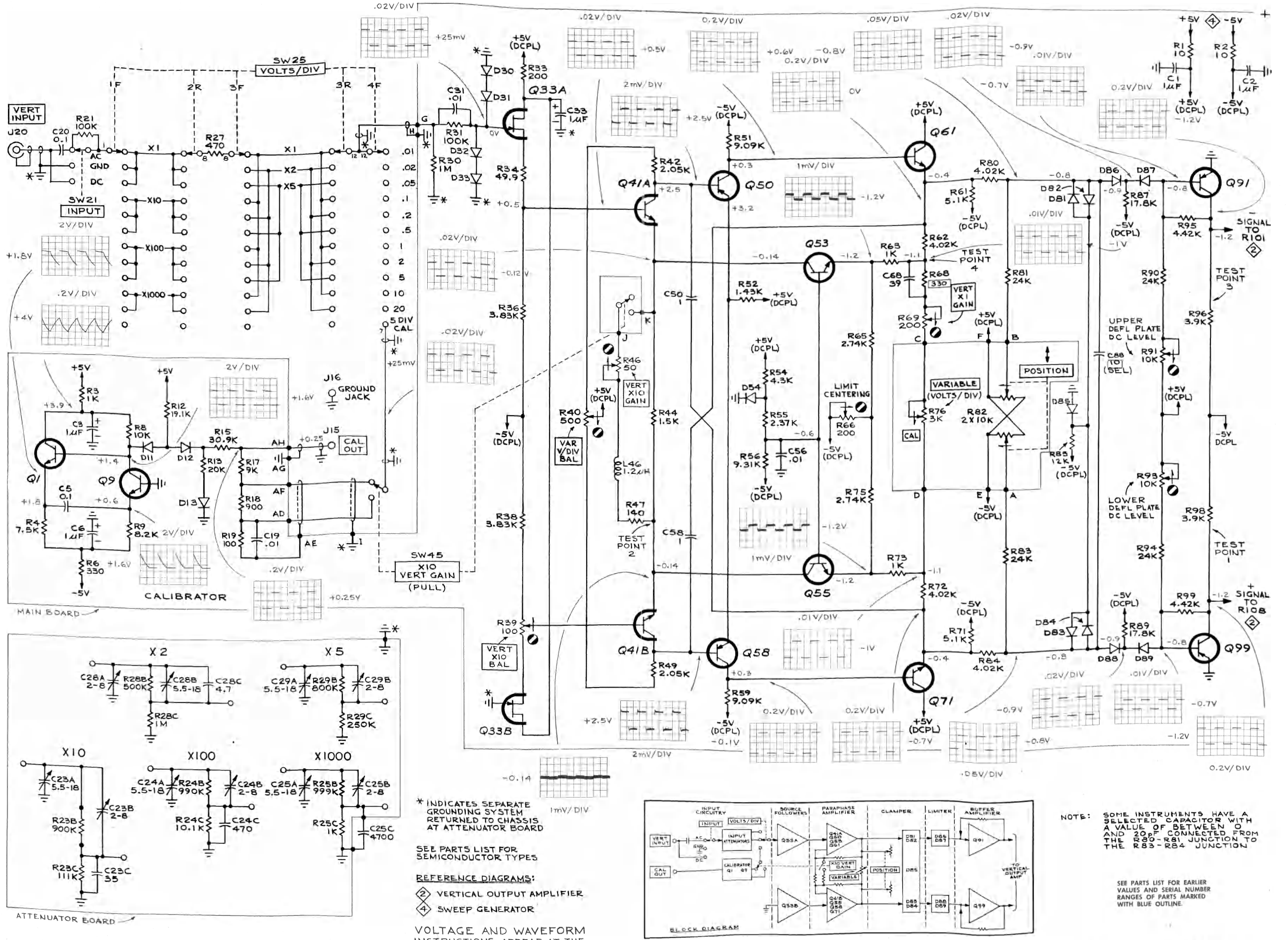
VOLTAGE AND WAVEFORM INFORMATION

Typical voltages and waveforms are printed on the schematics with blue ink. The voltages were taken with a non-loading voltmeter. The waveforms are reproductions of photographs obtained with a Tektronix C12 Camera System and Projected Graticule installed on an oscilloscope with a 7 MHz vertical bandwidth, 1 mV/division sensitivity, and an input impedance of 1 MΩ in parallel with 20 pF. Some slight deviations from the voltages and waveforms can be expected between individual Type 323 Oscilloscopes. Variations may also be introduced because of the type of test equipment involved in reproducing the voltages or waveforms.

VOLTAGE comparisons should be made under the following conditions:

Diagram Number	Type 323 Oscilloscope Setup	
1, 2, 4, 6, 7	Power Source	Any
	VOLTS/DIV	20
	VARIABLE	CAL
	TIME/DIV	EXT HORIZ
	VAR	CAL
	INTENSITY	Fully CCW
	POWER	ON
	POSITION controls	Knobs in and set to midrange
	TRIGGER	Midrange
	Trig/Horiz Coupling	INT TRIG - AC
3	Same as above, except:	
	TRIGGER	+ AUTO
8	Power Pack disconnected and removed from the Type 323 Oscilloscope. See Operating Instructions section for removal information.	
	Power Pack connected to 115-V, 60 Hz AC line source.	
	Power Pack switch set at TRICKLE CHG.	

(Continued on diagram ⟨2⟩)



* INDICATES SEPARATE GROUNDING SYSTEM RETURNED TO CHASSIS AT ATTENUATOR BOARD

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS:

2 VERTICAL OUTPUT AMPLIFIER

4 SWEEP GENERATOR

VOLTAGE AND WAVEFORM INSTRUCTIONS APPEAR AT THE LEFT OF THIS DIAGRAM

NOTE: SOME INSTRUMENTS HAVE A SELECTED CAPACITOR WITH A VALUE OF BETWEEN 0 AND 20pF CONNECTED FROM THE R80-R81 JUNCTION TO THE R83-R84 JUNCTION

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

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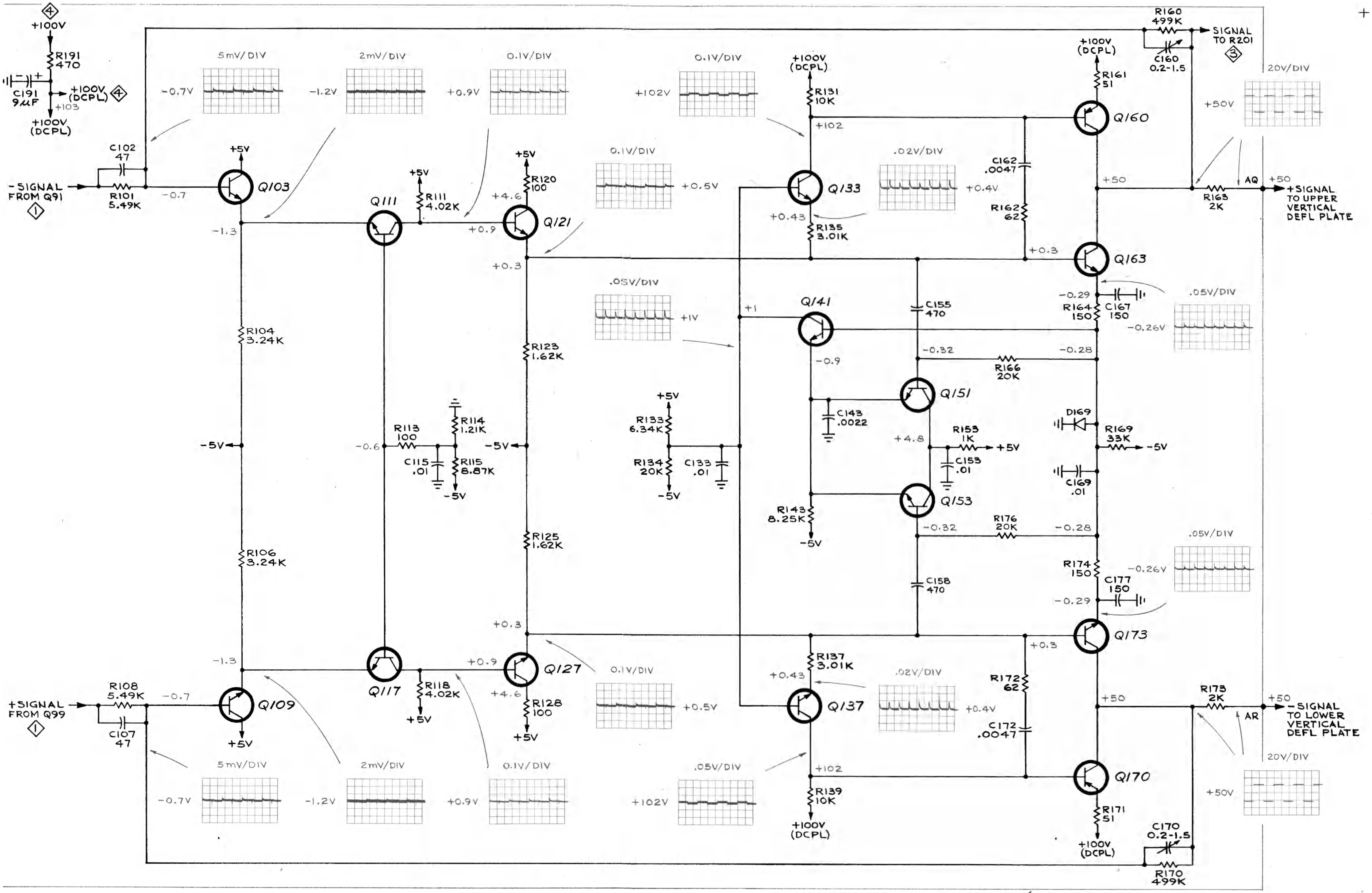
TYPE 323 OSCILLOSCOPE

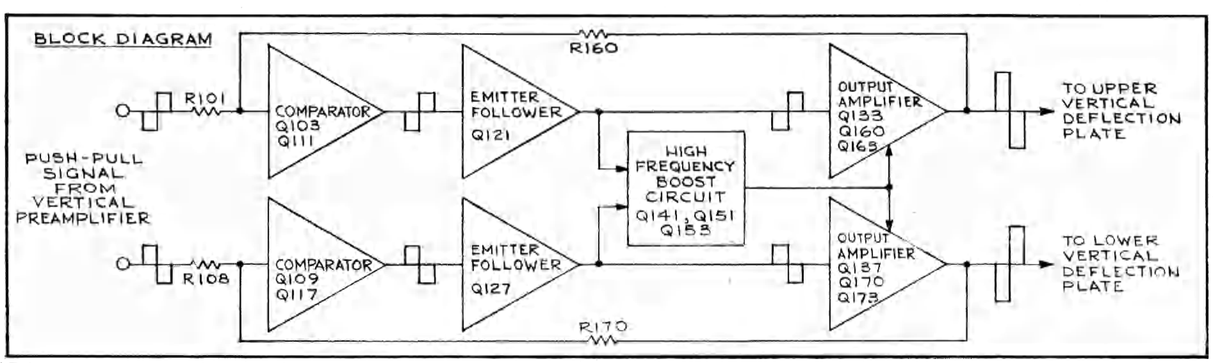
VERTICAL PREAMP 1

WAVEFORM comparisons should be made under the following conditions except as noted on individual schematics:

Diagram Number	Equipment Setup	
1, 2	Type 323 Oscilloscope	
	Voltage Source	Any
	VOLTS/DIV	5 DIV CAL
	VARIABLE	CAL
	TIME/DIV	.1 ms
	VARIABLE	CAL
	POWER	ON
	INTENSITY	Minimum intensity consistent with good viewing
	POSITION Controls	Knobs in and display centered
	TRIGGER	+ AUTO
	Trig/Horiz Coupling	INT TRIG - AC
	POWER	ON
	Test Oscilloscope	
	Externally triggered by positive slope from Type 323 Oscilloscope CAL OUT	
	Sweep Rate	0.5 ms/division
3, 4, 6	Same as for diagrams 1 and 2, except:	
	Type 323 Oscilloscope TIME/DIV at 50 μs	

(Continued on diagram 3)





VOLTAGE AND WAVEFORM INSTRUCTIONS APPEAR AT THE LEFT OF DIAGRAM ⟨1⟩

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

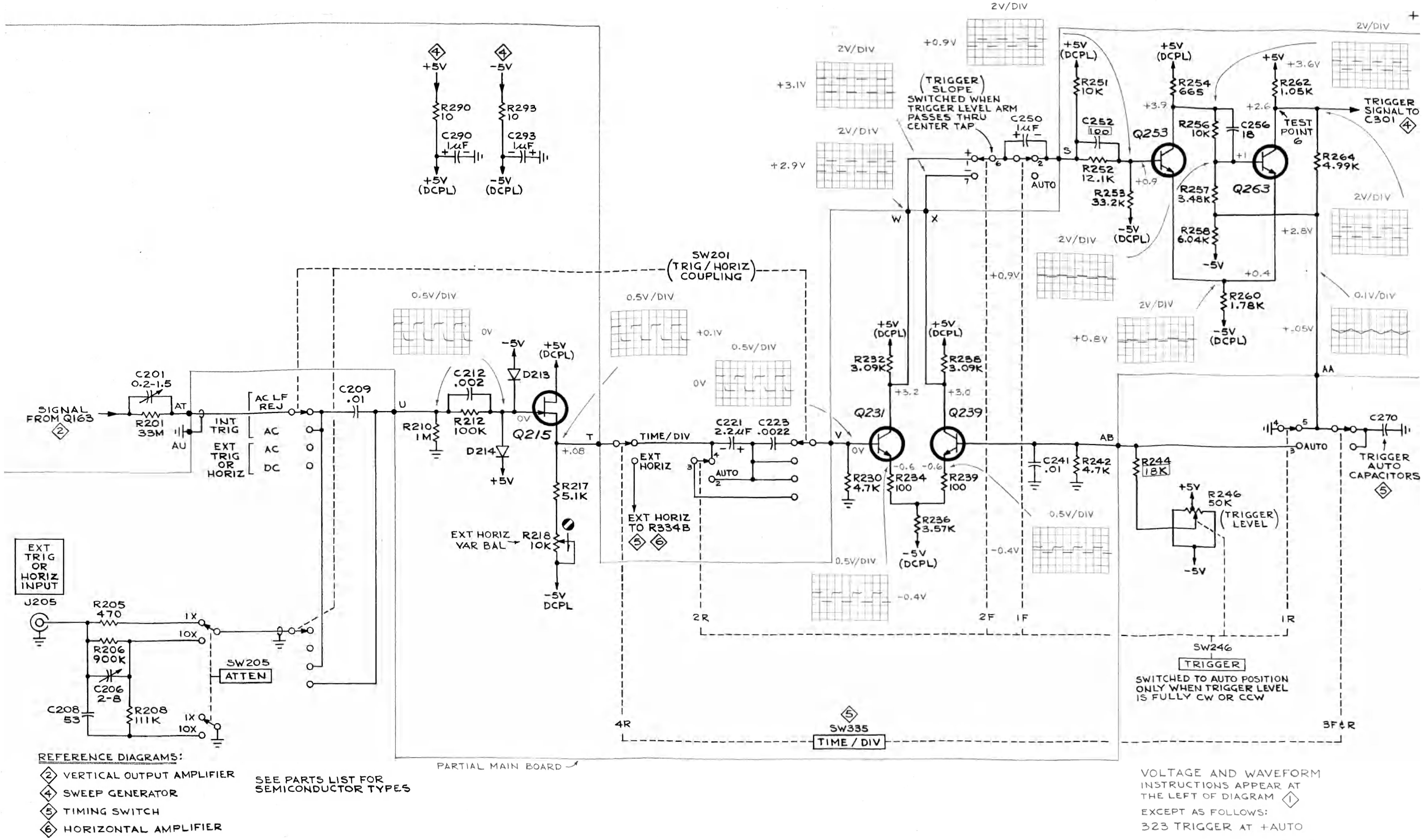
REFERENCE DIAGRAMS:

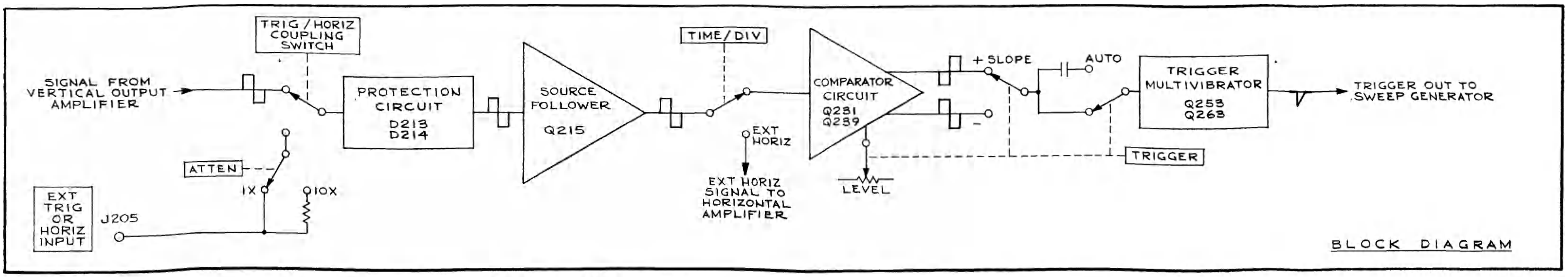
⟨1⟩ VERTICAL PREAMP
⟨3⟩ TRIGGER GENERATOR
⟨4⟩ SWEEP GENERATOR

VERTICAL OUTPUT AMPLIFIER ⟨2⟩

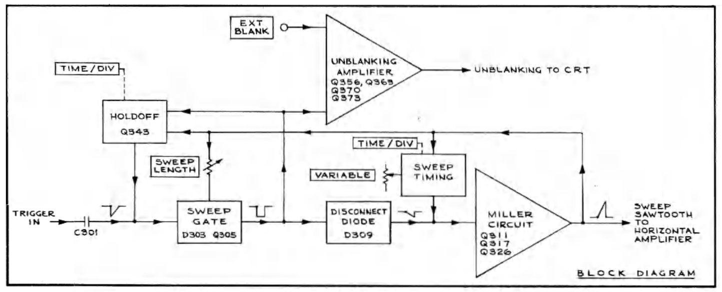
MRH 168

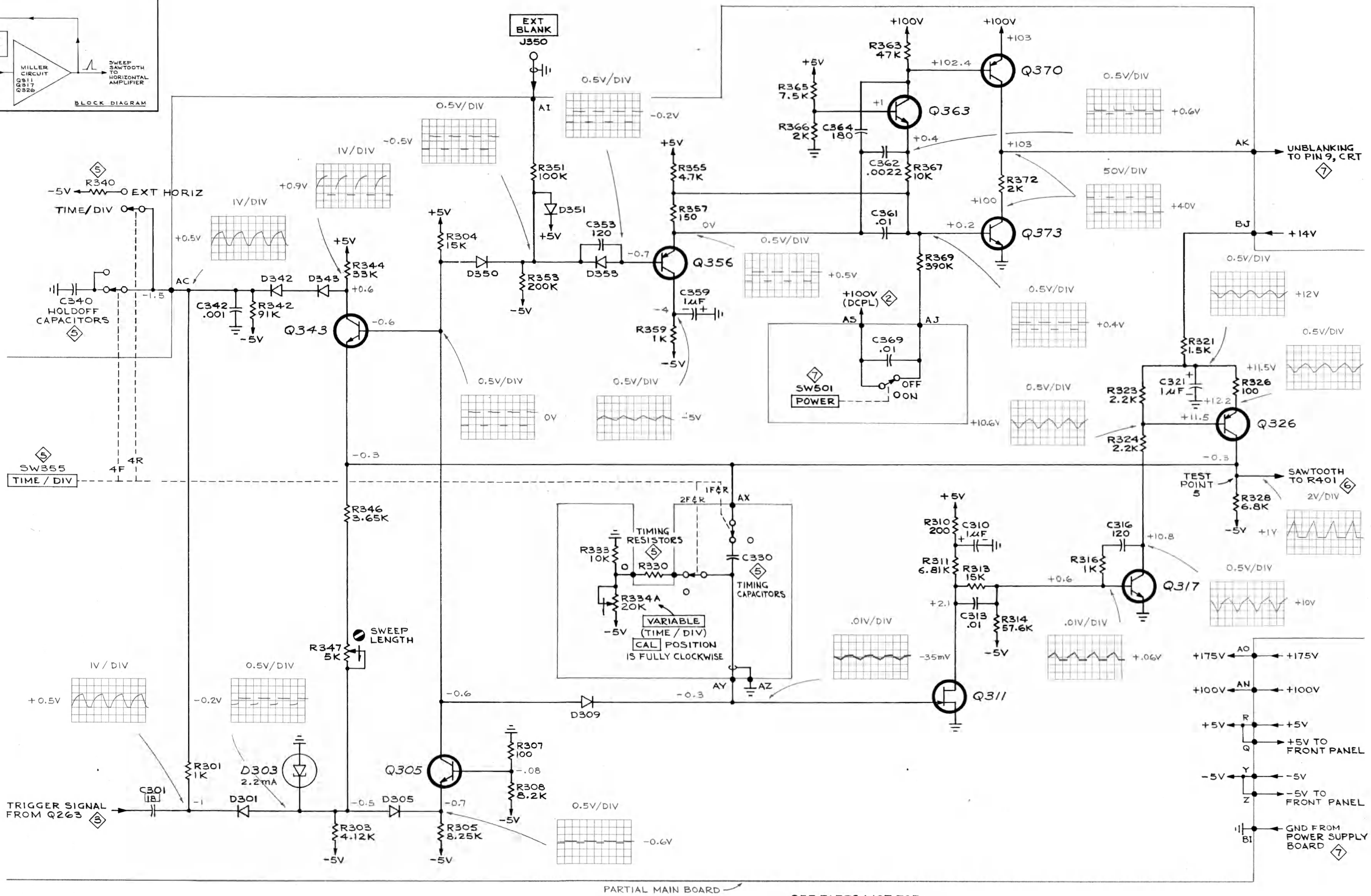
Diagram Number	Equipment Setup
7	Type 323 Oscilloscope
	Power Regulator circuit board swung out of compartment for access. See Maintenance section for instructions.
	Power Source: 7.5 V EXT DC (AC or internal battery power may be used, but deviations in pulse amplitude and frequencies will be noted).
	VOLTS/DIV: 20
	TIME/DIV: EXT HORIZ
	INTENSITY: Fully CCW
	POSITION Controls: Knobs in and set to midrange
	TRIGGER: Midrange
	POWER: ON
	Test Oscilloscope
	Externally triggered by positive slope from terminal I of the Power Supply circuit board.
	Sweep Rate: 10 μs/division
8	Type 323 Oscilloscope
	Power Pack disconnected and removed from the Oscilloscope. See Operating Instructions section for removal information.
	Power Pack Switch: TRICKLE CHG
	Test Oscilloscope
	Time/division: 5 ms
	Triggering: Line
	Slope: +





SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.





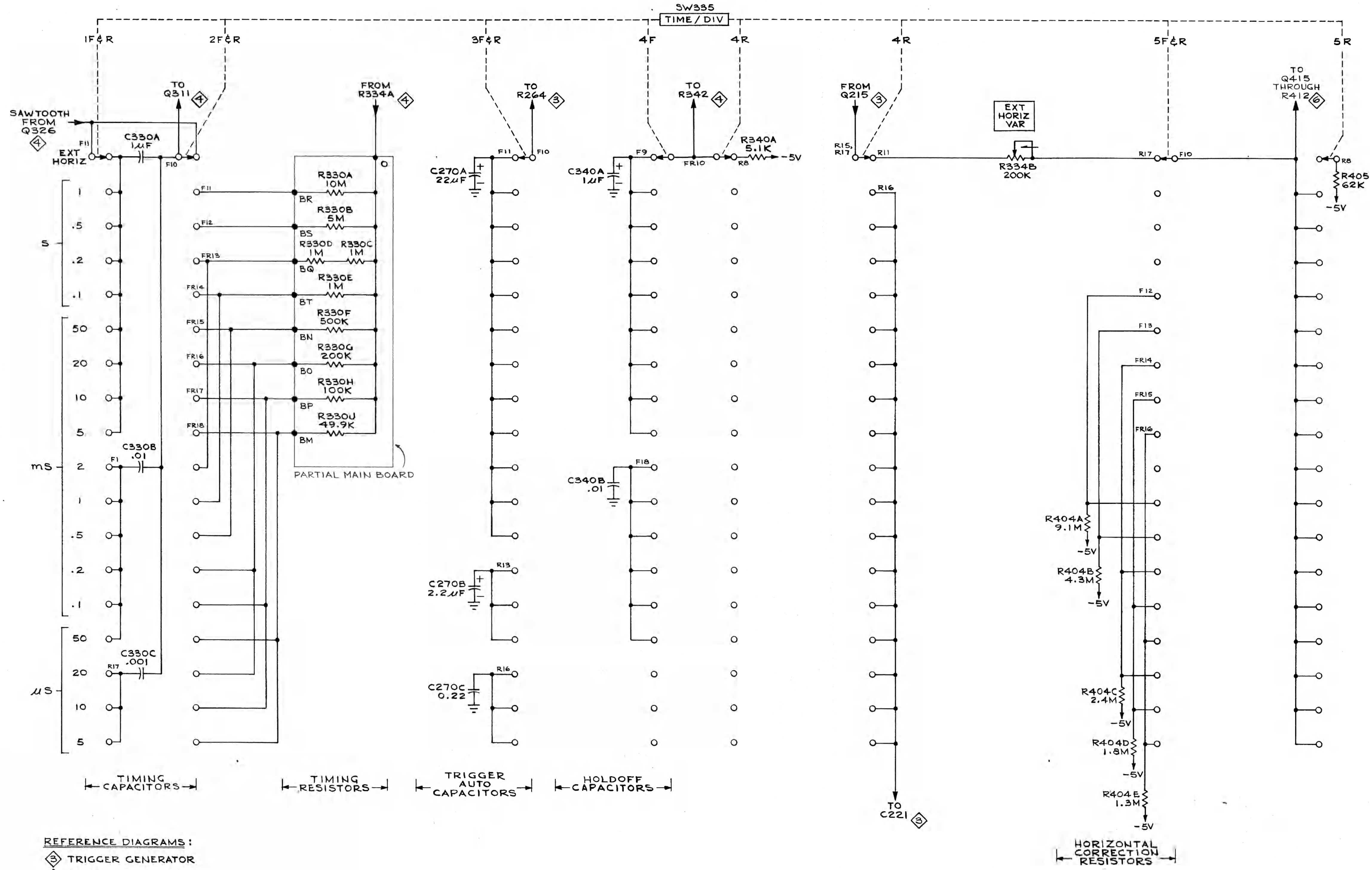
SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

VOLTAGE AND WAVEFORM INSTRUCTIONS APPEAR AT THE LEFT OF DIAGRAM 1

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS:

- 2 VERTICAL OUTPUT AMPLIFIER
- 3 TRIGGER GENERATOR
- 5 TIMING SWITCH
- 6 HORIZONTAL AMPLIFIER
- 7 POWER REGULATOR & CRT

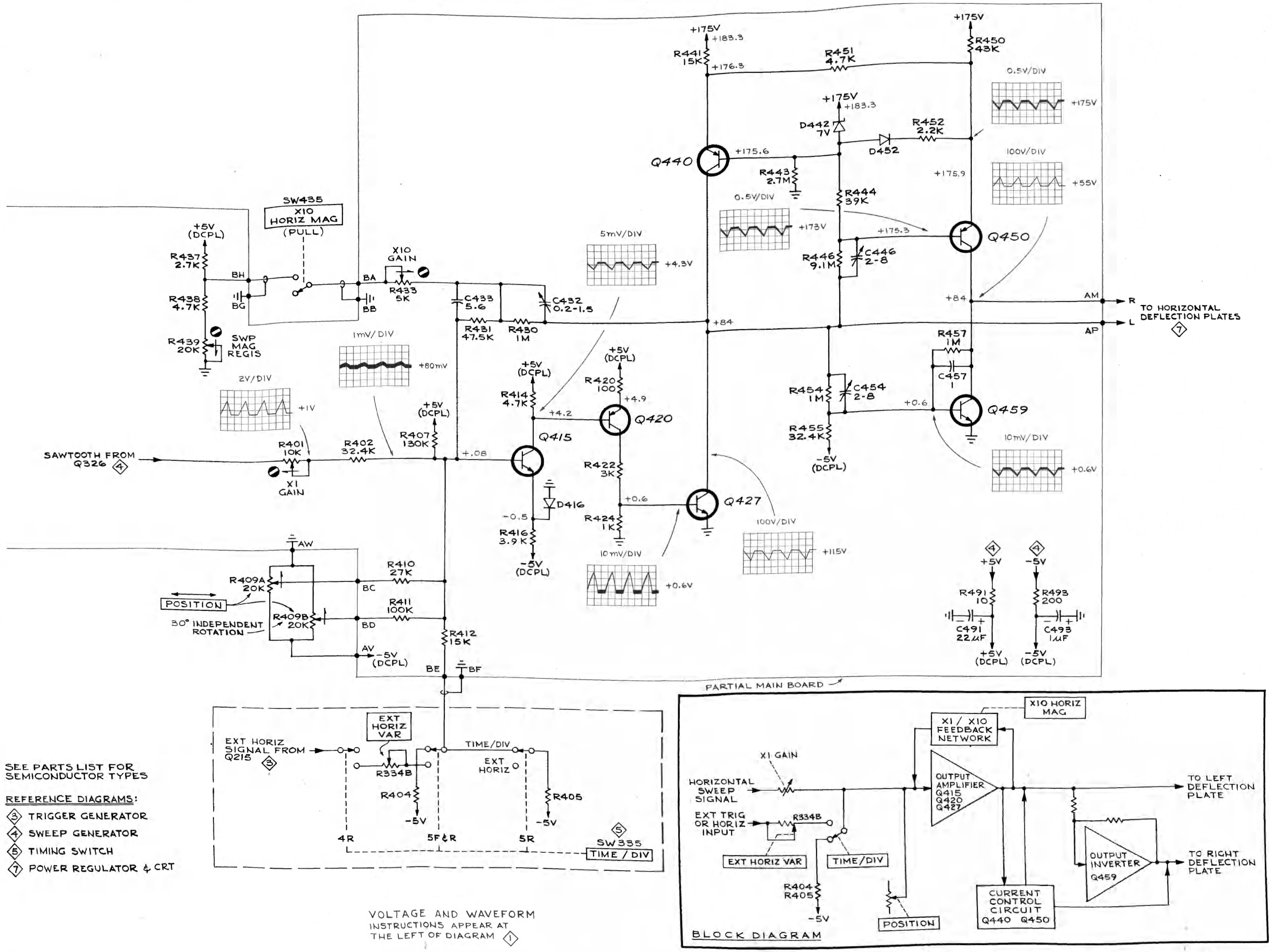


REFERENCE DIAGRAMS:

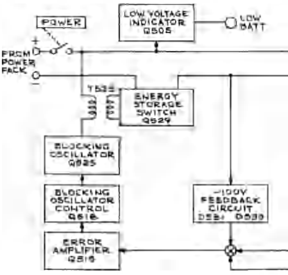
3 TRIGGER GENERATOR

4 SWEEP GENERATOR

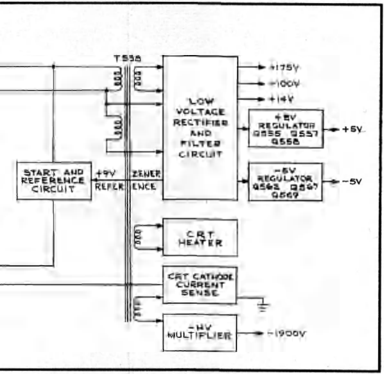
6 HORIZONTAL AMPLIFIER



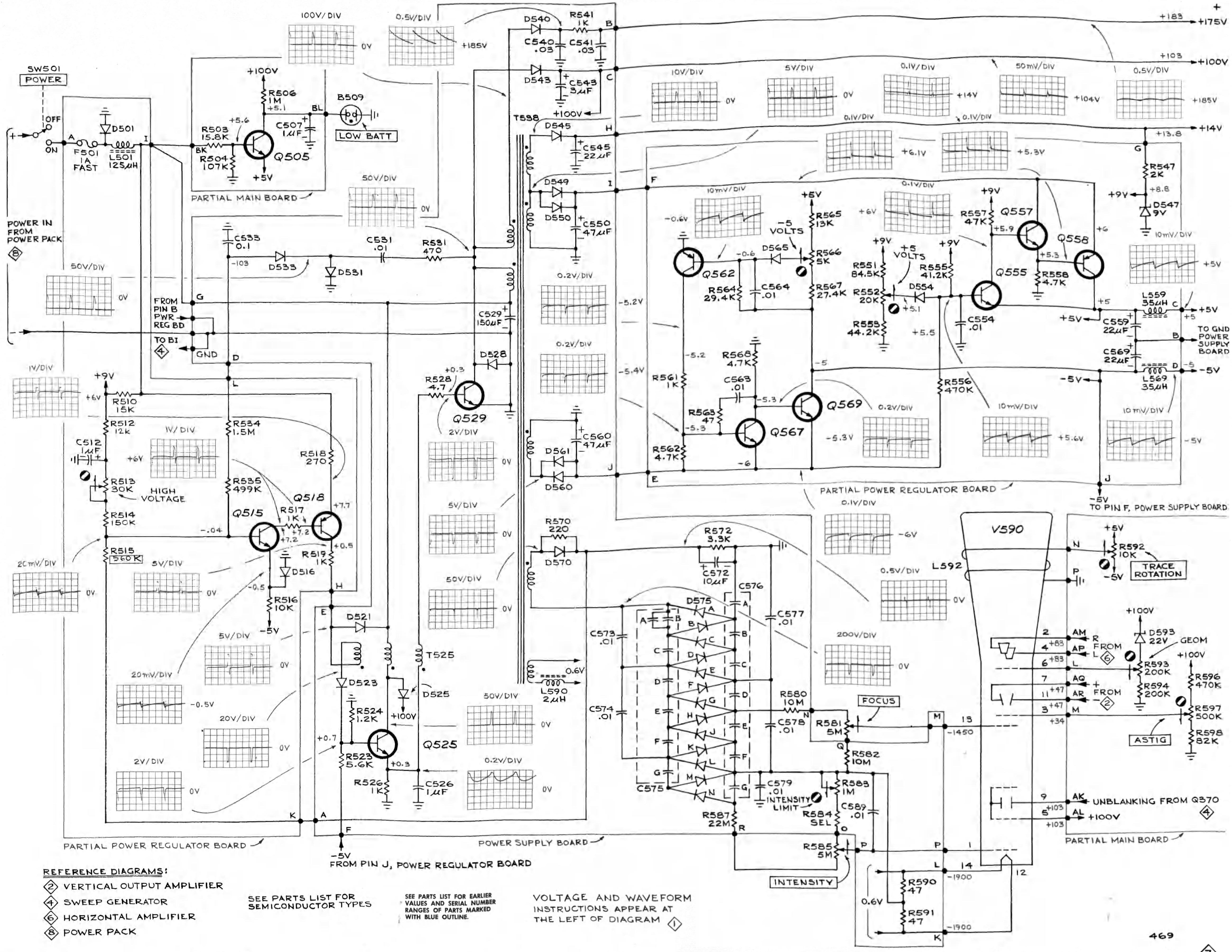
VOLTAGE AND WAVEFORM INSTRUCTIONS APPEAR AT THE LEFT OF DIAGRAM 1



BLOCK DIAGRAM



T538
LOW VOLTAGE RECTIFIER AND FILTER CIRCUIT
+175V
+100V
+14V
+5V REGULATOR Q555 Q557 Q558
+5V
-5V REGULATOR Q562 Q567 Q569
-5V
START AND REFERENCE CIRCUIT
+9V ZENER REFERENCE
CRT HEATER
CRT CATHODE CURRENT SENSE
-HV MULTIPLIER
-1900V



REFERENCE DIAGRAMS:

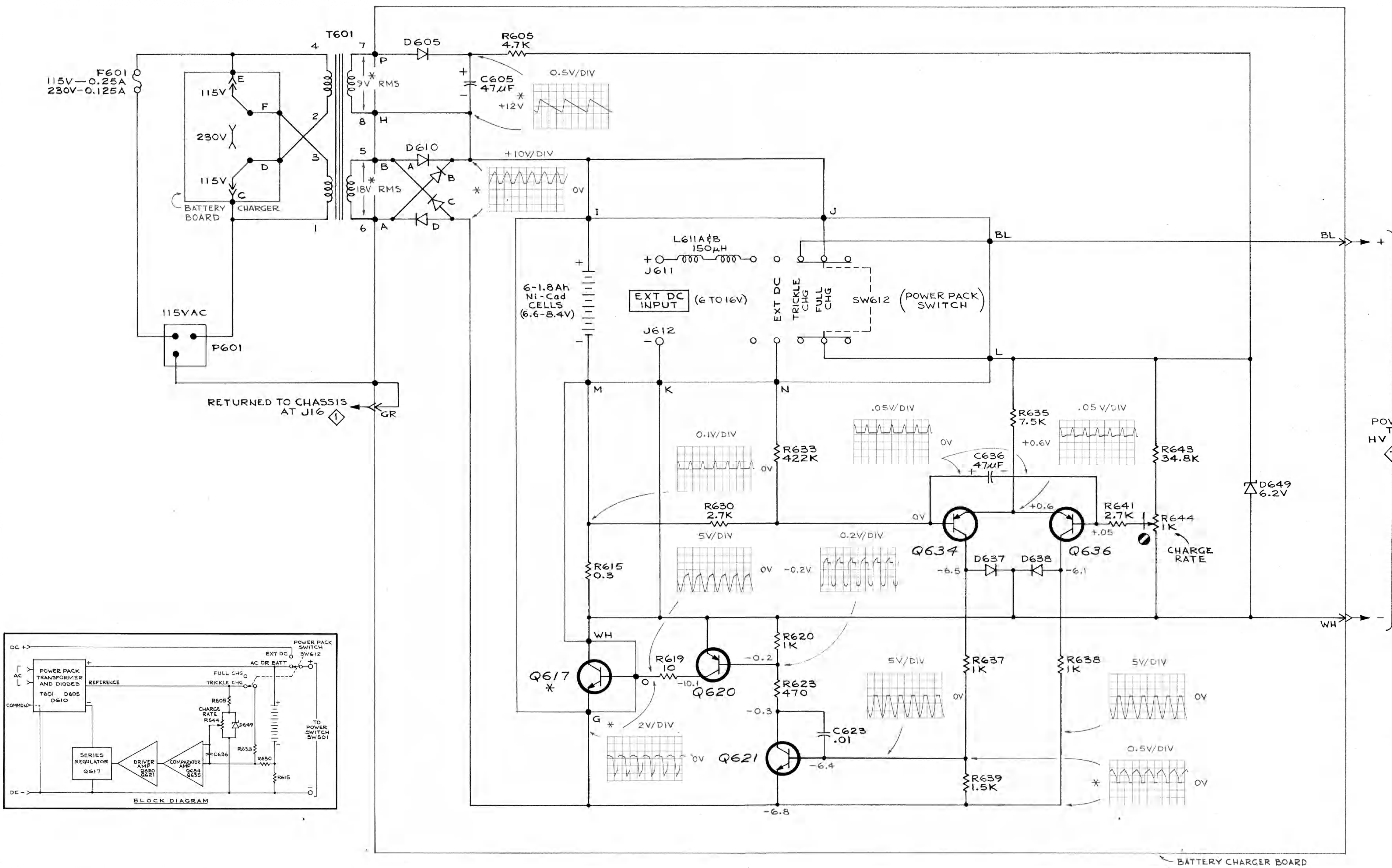
2 VERTICAL OUTPUT AMPLIFIER
4 SWEEP GENERATOR
6 HORIZONTAL AMPLIFIER
8 POWER PACK

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

VOLTAGE AND WAVEFORM INSTRUCTIONS APPEAR AT THE LEFT OF DIAGRAM 1

469



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

* TRANSISTOR IS HEAT SINKED

REFERENCE DIAGRAMS:

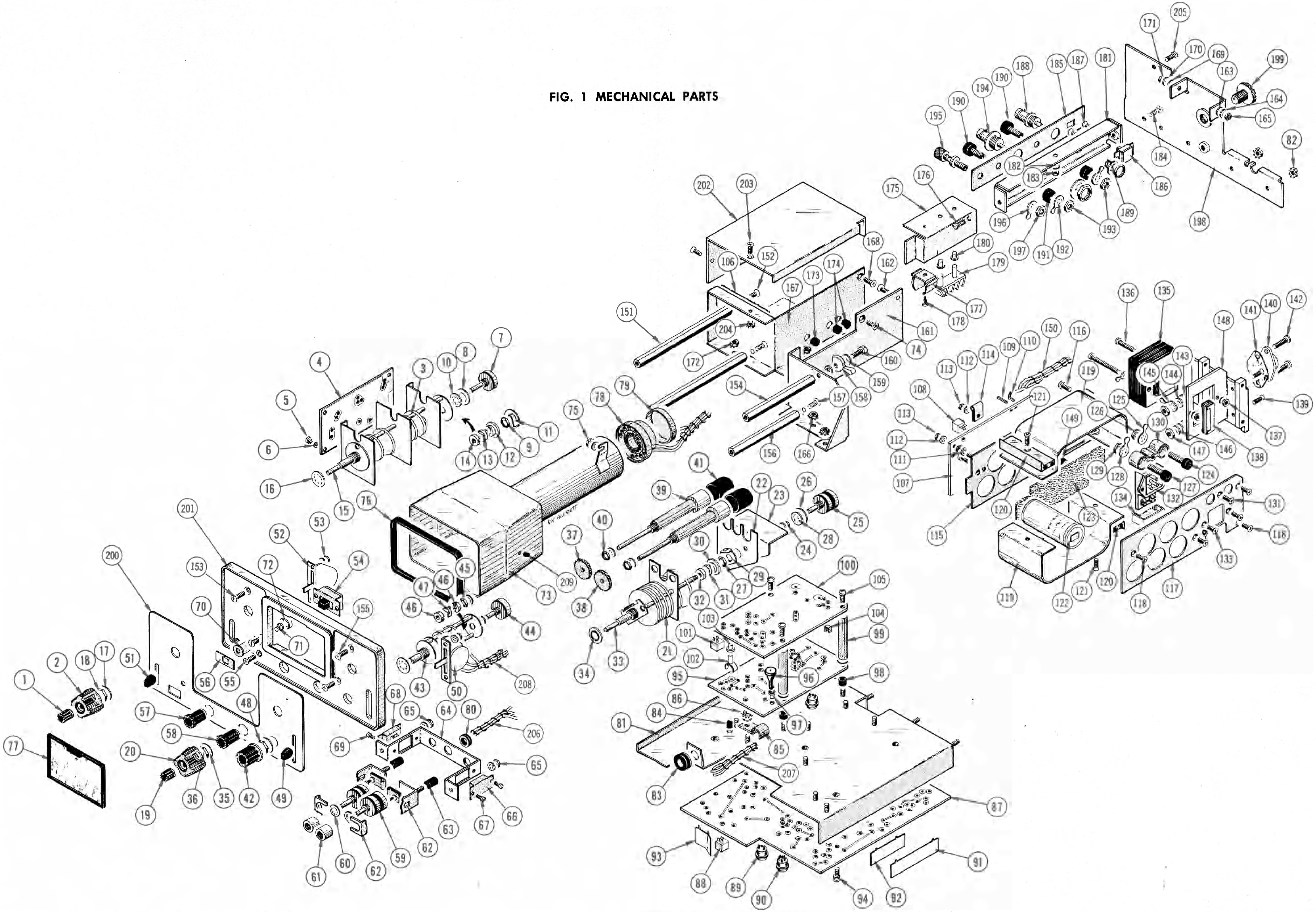
① VERTICAL PREAMP

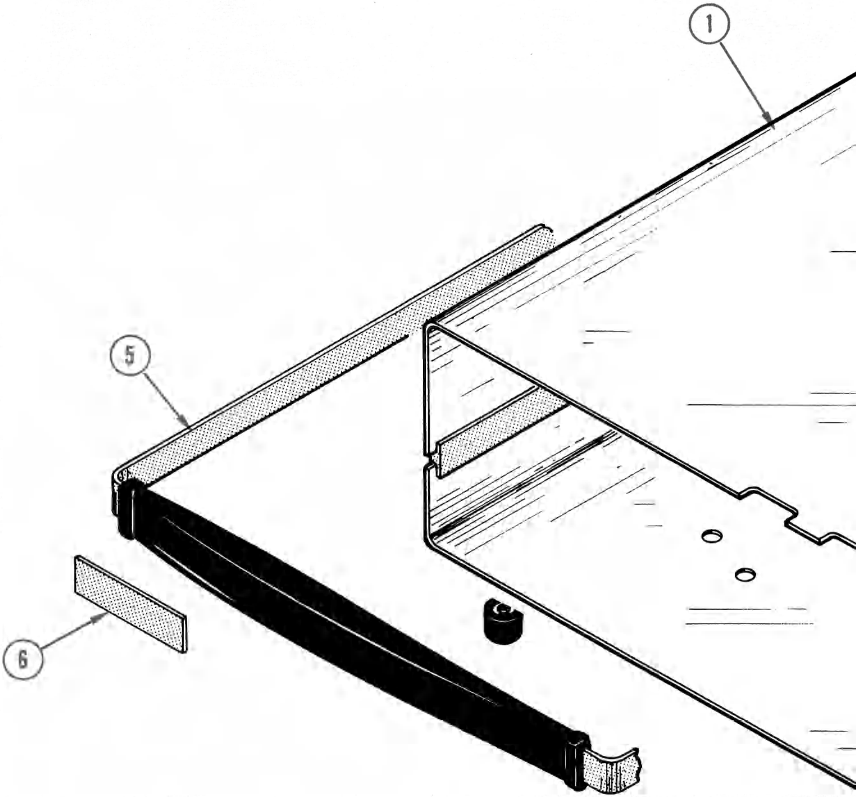
⑦ POWER REGULATOR & CRT

VOLTAGE AND WAVEFORM INSTRUCTIONS APPEAR AT THE LEFT OF DIAGRAM ①

* DIFFERENTIAL MEASUREMENT BETWEEN INDICATED POINTS

FIG. 1 MECHANICAL PARTS





TYPE 323 OSCILLOSCOPE

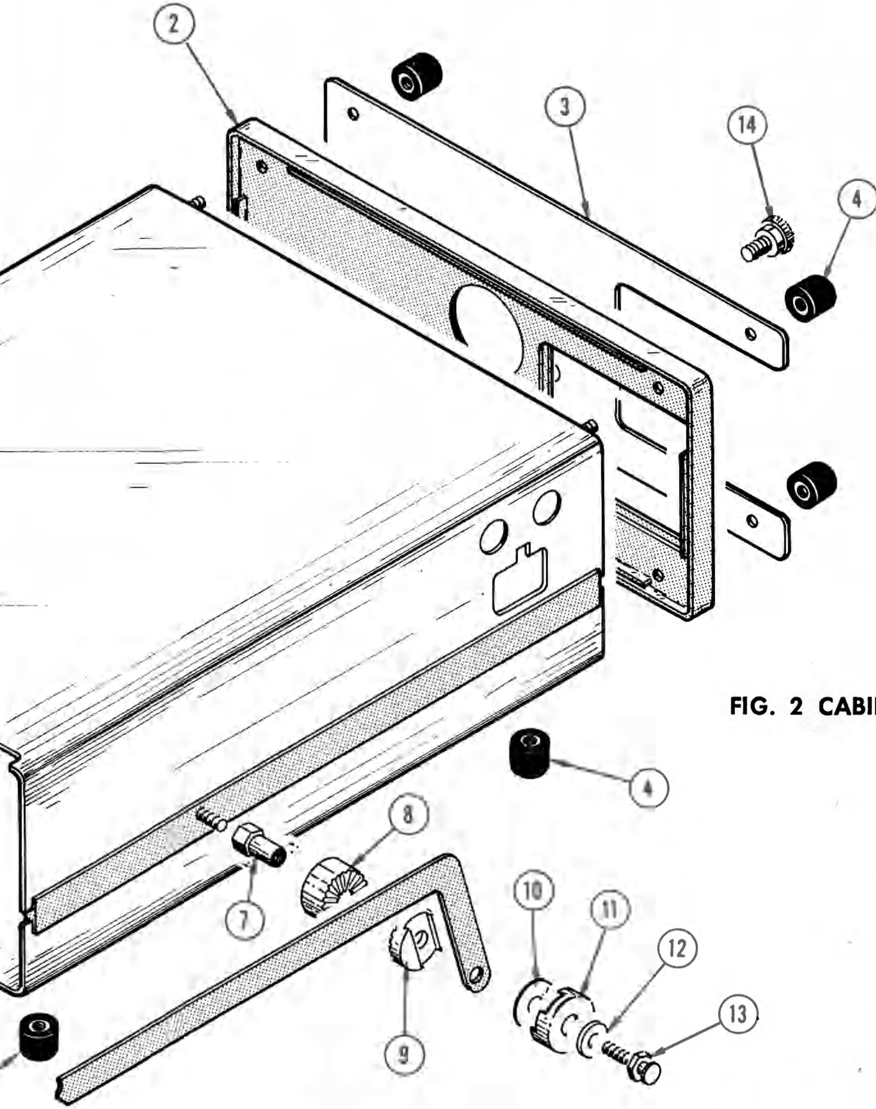
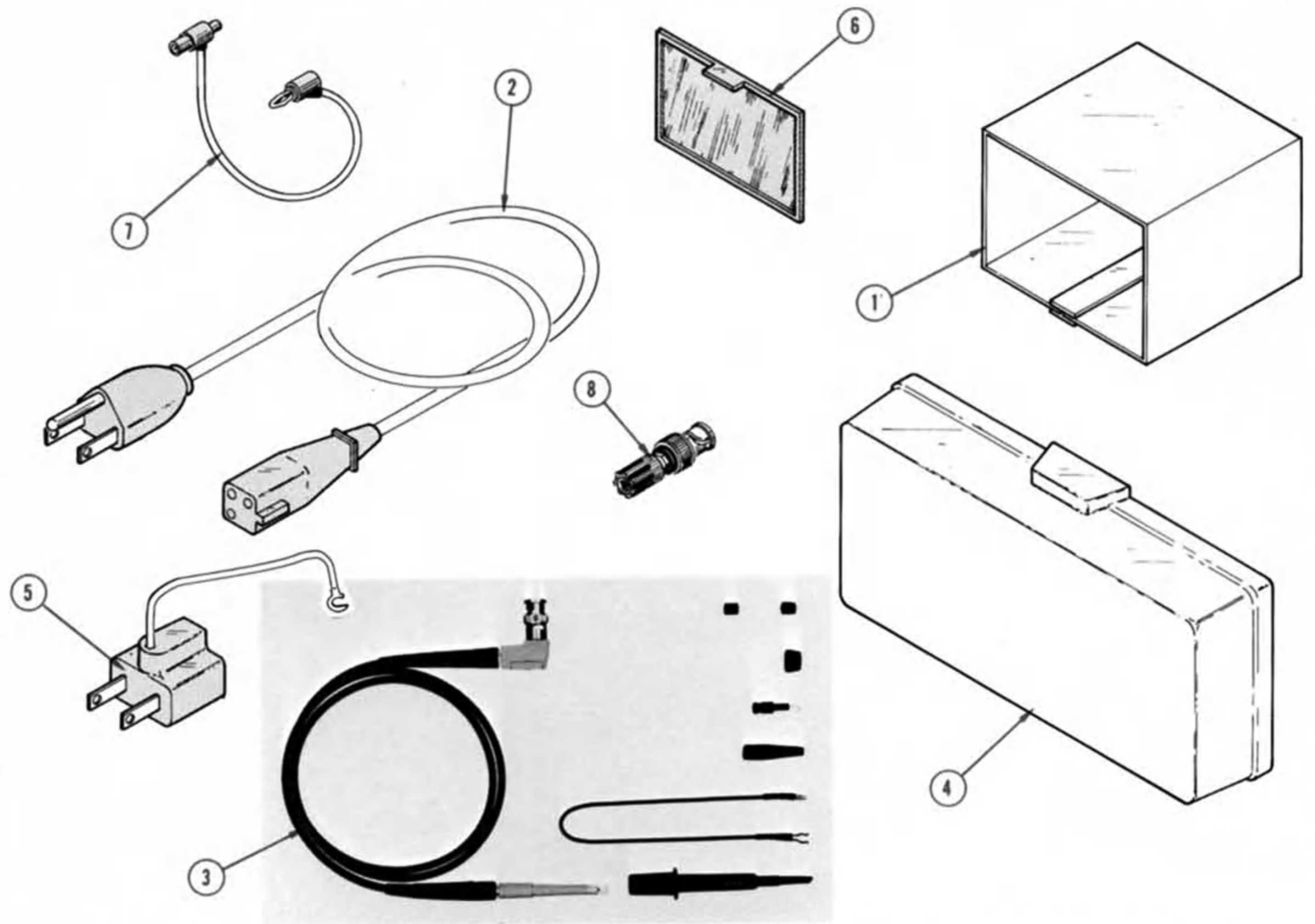


FIG. 2 CABINET

OPTIONAL ACCESSORIES

016-0119-00	1	POWER PACK
016-0112-00	1	COVER, protective, oscilloscope

FIG. 3 STANDARD ACCESSORIES



A

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-1	016-0247-01			1	VIEWING HOOD
-2	161-0043-00			1	CABLE ASSEMBLY, power, 6 foot
-3	010-0223-00			1	PROBE PACKAGE, P6049
-4	200-0812-00			1	COVER, panel
-5	103-0013-00			1	ADAPTER, 3 to 2 wire
-6	426-0403-00			1	FILTER, light, smoke gray
-7	012-0089-00			1	CORD, patch, BNC to banana, 6 inch, red
-8	103-0033-00			1	ADAPTER, BNC to binding post
	346-0051-00			1	STRAP ASSEMBLY (not shown)
	016-0113-00			1	ACCESSORY PACK (not shown)
	070-0750-00			2	MANUAL, instruction (not shown)

ⒶI

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.

TEXT CORRECTION

Section 4 Maintenance

Page 4-4

ADD: the following information at the end of page 4-4:

Battery Troubleshooting. Before troubleshooting the battery, determine that the problem is actually in the battery. The Master Troubleshooting Chart (Fig. 4-3) may indicate that the battery or charger is at fault; unusually short internal battery operating time (between a 16 hour full charge and the time that the LOW BATT lamp starts flashing) may indicate that either the battery or charger or the LOW BATT lamp circuit is at fault or that an excessive circuit-drain exists in the Oscilloscope.

Circuit drain can be checked as follows:

(1) Apply external DC power (between 6 and 16 V) to the EXT DC connectors, inserting a 0 to 0.5 A ammeter in series with one of the power leads.

(2) Set the Oscilloscope controls as follows:

TIME/DIV	1 ms
POSITION controls	in and centered
VOLTS/DIV	5 DIV CAL
TRIGGER	+ AUTO
Trig/Horiz Coupling	INT TRIG - AC
Power Pack Switch	EXT DC
POWER	ON
INTENSITY	Adjusted for minimum brightness necessary for good viewing

(3) Multiply the applied DC voltage by the current indicated on the ammeter. The product should be approximately 1.6 W. A product of 2 W or more is an indication of excessive circuit-drain, and should be checked further by performing a Calibration Procedure or by otherwise troubleshooting the Oscilloscope. If the product is between 1.25 and 2 W, circuit-drain can be considered as normal and the trouble can be assumed to be in the battery or charger.

The charger and LOW BATT lamp circuit can be checked by first checking the resistance of R615 and then performing Steps 1and 9 of the Calibration Procedure.

If circuit-drain and the charger have been exonerated as the source of trouble by the preceding checks, the battery can be assumed to be at fault. If the probelm is a battery-operating time of shorter duration than that specified, it may be due to a faulty cell(s) or to a general battery degradation caused by abuse, old age or a high number of charge-discharge cycles. In either case, battery-operating time may be sufficiently long to satisfy operating demands, and further troubleshooting can be ignored. However, if internal battery-operating time is extremely short and/or rated internal battery-operating time is to be regained, continue with this procedure.

To check the battery, proceed as follows:

(1) Complete a 24 hour FULL CHG cycle with the Oscilloscope POWER switch OFF.

(2) Set the controls as specified for checking circuit-drain except that the Power Pack switch should be set to FULL CHG and the external power should be disconnected.

(3) Check the voltage between terminals M and I of the Battery Charger circuit board to ascertain that no dead or shorted cells exist. If the battery voltage is below 7.2 V, individual cell voltages should be checked. To check individual cells, remove the battery as explained in the Disassembly and Assembly instructions in this section. Then use jumper wires to reconnect the battery during this check, observing proper polarity. All cell voltages should be in excess of 1.2 V. Replace bad cells or the battery in accordance with the information given in the Disassembly and Assembly instructions. If individual cells are replaced, recharge the battery for 24 hours before continuing with this procedure.

(4) Continue operating the Oscilloscope for approximately 2 hours. Again check individual cell voltages. Any cell whose voltage is more than 50 mV below the average voltage of the rest should be considered as suspect. Final determination of its value can be made in step 5. If individual cells are replaced, recharge the battery for 24 hours before continuing with this procedure.

(5) Continue operating the Oscilloscope until the LOW BATT lamp blinks. If less than 4 hours time is obtained, the individual cell voltages should again be checked against the information given in the preceding paragraph. If individual cell and average voltage are both low, the entire battery should be replaced. If operating time is above 4 hours, cells or battery can be replaced at the discretion of the customer.

TEXT CORRECTIONS

Section 1 Specification

Page 1-2 VERTICAL DEFLECTION SYSTEM

CHANGE: portions of Step Response to read:

Step Response		
Aberrations at .01 VOLTS/DIV	Peak aberrations not to exceed +2% or -2%; total peak-to-peak aberrations not to exceed 3% ($-15^{\circ}C$ to $+55^{\circ}C$).	VARIABLE VOLTS/DIV control set to CAL
Aberrations at all other VOLTS/DIV switch positions		
$0^{\circ}C$ to $+55^{\circ}C$	Peak aberrations not to exceed +3% or -3%; total peak-to-peak aberrations not to exceed 3%.	
$-15^{\circ}C$ to $+55^{\circ}C$	Peak aberrations not to exceed +4% or -4%; total peak-to-peak aberrations not to exceed 4%.	

Page 1-6 POWER SUPPLY

CHANGE: portions of Battery Operation to read:

Battery Operation		
Batteries	Six size C nickel-cadmium cells.	
Charge time (Power Pack switch set to FULL CHG)		At least 16 hours.
Operating time (batteries charged at $+20^{\circ}C$ to $+25^{\circ}C$, operated at $+20^{\circ}C$ to $+30^{\circ}C$)		
10 microamperes or less cathode current (low intensity)	Calibrator waveform displayed, 7 hours. Six-division four megahertz signal displayed, 4 hours.	
300 microamperes cathode current (full intensity)	Calibrator waveform displayed 4.4 hours. Six-division four megahertz signal displayed, 3 hours.	

Section 2 Operating Instructions

Page 2-5 POWER PACK OPERATING PROCEDURE, General

CHANGE: the third line of the second paragraph to read:

erating conditions for approximately 7 hours. Actual oper-

ELECTRICAL PARTS LIST CORRECTION

CHANGE TO:

J15	136-0140-01	Jack tip
J350	136-0140-01	Jack tip

POWER PACK

J611	136-0139-01	Jack tip
J612	136-0140-01	Jack tip